THE BIONOMICS OF *DIOPSIS* (DIPTERA; DIOPSIDAE) AND OF *EPILACHNA SIMILIS* (COLEOPTERA, COCCINELLIDAE) ON *ORYZA SATIVA* L. IN THE ACCRA PLAINS

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Master of Science
(Crop Science)

by

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DECLARATION

I hereby declare that, except for references to other people's work which have been duly cited, this work is the result of my own original research and that this thesis has neither in whole nor in part been presented for another degree elsewhere.

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(SUPERVISOR)

Date: 21/8/72

A B S T R A C T

The biology of Diopsis species (Diptera; Diopsidae) and Epilachna similis (Coleoptera; Coccinellidae) was studied on the Accra Plains. Of the three species of Diopsis found, D. thoracica caused the most severe damage to rice. All the developmental stages of these insects are described and keys are provided for identifying all the various stages of the Diopsis species. D. thoracica exhibits sexual dimorphism with regard to the inter orbital distance. A high stalk infestation of forty-eight per cent was recorded in the major rainy season. The parasites and altenate hosts of these insect species are discussed. Artificial infestation of rice stalks with the larvae of D. thoracica demonstrated that a single larva could destroy 3 - 6 stalks during its life time leading to a loss of about nine percent in yield.

All the developmental stages of E. similis are described and a key provided for identifying the four larval instars. Possible control measures against the Diopsis species and Epilachna similis are discussed.

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ABBREVIATIONS AND SYMBOLS

cm	centimeter
cs	cephalopharyngeal skeleton
df	degrees of freedom
Fig.	Figure
°C	degrees Centigrade
gm	gram
hrs	hours
Inf.	Infestation
Max.	Maximum
Min.	Minimum
mm	millimeter
MS	Mean Square
No.	Number
NS	Non Significant
RH	Relative Humidity
SD	Standard Deviation
SS	Sum of Squares
Temp	Temperature
*	Significant at 5% level
**	Significant at 1% level
%	Percent; Percentage.

1. INTRODUCTION

Rice, Oryza sativa L. is now firmly established as one of the staple foods in Ghana and its production has attracted national attention in recent years. Ghartey (1970) estimated that Ghana consumes about 90 million kilograms of rice annually. Nearly half of this amount is imported at a cost of approximately seven million cedis and it is assumed that the import bill will stand at eleven million cedis by 1975 if rice production is not stepped up. With this in mind the Ministry of Food and Agriculture has intensified its efforts in providing facilities for large scale cultivation of both irrigated and rain-fed rice. The major areas of cultivation now include the Northern and Upper Regions, the Brong Ahafo Region, the Western Region, the Volta Region and parts of the Accra Plains.

While the large scale cultivation of rice is likely to save some foreign exchange, it must not be forgotten that if effective control measures are not taken against pest problems the aims cannot be achieved. Insect pests constitute one of the principal causes of low yields in the major rice growing areas of the world. Roughly one hundred insect species are known to infest and damage rice plants throughout the world and larval stem borers are among the most serious pests of this crop (Anon, 1969, 1970; Akinsola, 1970). Most of these larvae belong to the two insect orders, Lepidoptera and Diptera. They bore into the rice stem shortly after hatching and for most of their life remain inside the stem, feeding either killing it, or so injuring the plant that it produces little or no crop.

The lepidopterous larval borers which belong to the families Pyralidae and Noctuidae have been recorded as major pests of rice in almost all the rice growing regions of the world, including West Africa.

Among the Diptera the genus Diopsis contains species which are borers of rice and other graminaceous crops. In West Africa the damage caused by Diopsis species is considered to be more serious than that caused by the lepidopterous borers (Lever, 1969; Anon, 1970). Recent reports by Van Halteren (1970), Simmonds (1970) and Schroder (1971) indicate that Diopsis spp pose a threat to rice cultivation in South-Eastern Ghana. However, none of them gave the degree of infestation.

Quite recently attention has also been drawn by Breniere (1969) and Schroder (1970) to outbreaks of the leaf feeding insect Epilachna similis Muls. on some rice farms in the Eastern and Volta Regions.

The importance in Ghana of Diopsis spp and E. similis as pests of rice is not quite clear. The present study aims at providing some of the basic information on these insects.

2. REVIEW OF LITERATURE

2.1 *Diopsis* spp (Diptera; Diopsidae)

The *Diopsis* spp are found mainly in Africa and Asia (Descamps, 1957b).

As peculiar looking stalked-eye flies adult diopsids attracted the attention of collectors as far back as 1775, yet very little was known about the genus until 1957 when Descamps (1957a; b) gave an account of the biology and morphology of twenty species of the family Diopsidae in Northern Cameroun. Before then the literature contained only scanty observations on the behaviour of the adults of a few species with practically no information on the immature stages.

Since very little was known about the *Diopsis* spp until quite recently, it is not certain when they became pests of rice and other graminaceous crops. Simmonds (1970) cited Mallay (1920) as having recorded *Diopsis apicalis* Dalm. in association with the maize stalk borer *Busseola fusca* Fuller in South Africa. Compiling a list of insect pests of rice in Northern Cameroun Descamps (1956) recognised *Diopsis thoracica* Westwood, *Diopsis tenuipes* Westwood, *Diopsis collaris* Westwood, and *Diopsis serveillei* Marquart as stem borers. Descamps (1957b) again recorded fifteen diopsids on graminaceous plants in Northern Cameroun. Out of this number seven were said to be very serious pests and most of them were on rice with a few on millet and sorghum. The same work also reported the occurence of a number of Diopsis spp in the Congo, Natal, East Africa, Senegal, Kenya, Zambezi, Rhodesia, Uganda, Mozambique, Guinea, Gabon and Somalia. Van Bruggen (1961) has recorded D. thoracica, D. tenuipes, and D. apicalis in South Africa. Jerath (1965) and Akinsola (1970) observed D. thoracica and D. apicalis as pests of rice in Nigeria but the attack was said to be mild. Jordan (1966) and Morgan (1970) reported that severe damage is done to rice in Sierra Leone by Diopsis spp and Brenière (1966;1969) made similar observations in Madagascar, Dahomey, Ivory Coast and Upper Volta. In Ghana, Van Halteren (1970) recorded D. thoracica and D. apicalis at the Kpong Agricultural Research Station and stated that the former is the most serious of all insect pests encountered on rice. Shortly after this Schroder (1970) reported that 35-60% of rice hills were damaged by Diopsis spp in the Volta Region.

2.2 Epilachna similis Muls. (Coleoptera; Coccinellidae)

The members of the family Coccinellidae are the well-known lady-bird beetles, the greater number of which are carnivorous and predaceous, feeding during both the larval and adult stages, on aphids, mealybugs and other insects. A comparatively small group are phytophagous and they constitute the subfamily Epilachninae to which the genus Epilachna belongs. Species of this genus have been recorded in many countries as pests of cucurbits, beans, cotton and several other crops. A well-known pest under this genus is the Mexican bean beetle Epilachna varivestis Muls. of North America.

The literature on the genus as a whole and Epilachna similis Muls. in particular is very scanty. Peacock (1914) observed that E. similis fed on the leaves of cotton in Nigeria. This was confirmed by Jerath (1965) who listed the same species as one of the important pests of rice and added other graminaceous crops to its host range. Smithers (1957) listed several species of Epilachna feeding on various crops in Southern Rhodesia and mentioned E. similis in particular as a pest of maize, oats, wheat, sorghum, barley and some pasture grasses. Similarly Walker (1958) recorded E. similis on rice and maize in East Africa. Schmutterer (1969) found this pest widely distributed on various gramineae in East Africa, Rhodesia, South Africa and Sudan and Brenière (1969) made similar observations in Senegal, Ivory Coast, Ghana and Dahomey. In Ghana the occurence of E. similis on rice has been confirmed by Van Halteren (1970), but while he maintained that this pest is of minor importance Schroder (1970) reported that the damage caused is severe in the Eastern and Volta Regions of the country.

3. THE AREA OF INVESTIGATION

The work carried out in this study was restricted to the Accra Plains which is located in the South-Eastern corner of Ghana between latitudes 6° 14' N and 5° 29' N and longitudes 0° 23' W and 0° 41' E. The area is approximately 3750 square kilometers and roughly triangular in shape. It is bounded on the west by the Akwapim Range and the Weija Hills, on the north and east by the lower Volta River and on the south by the Gulf of Guinea between the mouth of the Volta and a point ten miles west of Accra (Fig.1).

The area has a gently sloping topography. There are no permanent rivers and most of the major streams flow for only a few months during and after the rainy seasons and dry out to pools in the main dry seasons.

Mean annual rainfall ranges from 75cm at the coast to 125cm in the extreme north and the greater part of the plains receive less than 90cm with totals varying considerably from year to year. There are two rainy seasons; March to July which records the highest rains and September to December which is the minor season.

Temperatures are highest during the main dry season from December to February and lowest during the short dry season which is from July to August. Absolute minimum temperatures range between 13°C and 40°C but proximity to the sea and high altitudes such as the Akwapim Range reduces the temperature.

Humidities are high throughout the year. The average monthly

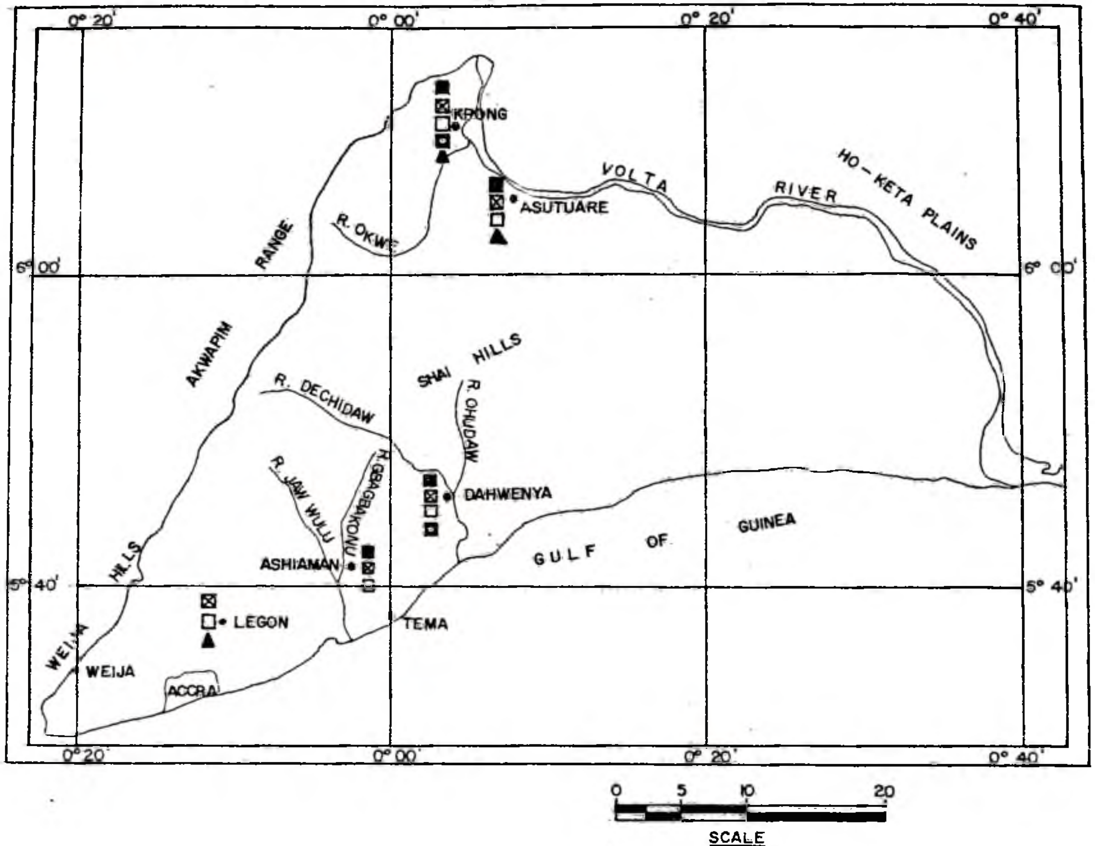

FIG. I. ACCRA PLAINS WITH THE SPECIES RECORDED AT THE PLACES VISITED.

KEY

■ D. THORACICA ☒ D. TENNIPES ▲ E. SIMILIS

□ D. ICHNEUMONEA ◘ D. SPECIES d

relative humidity are 60-75% in the afternoon and 91-97% at night.

There are little variations in daylengths. These seldom fall below or rise above 11 hours 50 minutes and 12 hours 25 minutes respectively.

The soils of the Accra Plains fall into seven major groups, viz. Shallow rocky soils, Red earths, Pallid sands, Grey earths, Black clays, Alluvial clays, and Leeve and dune sands (Brammer, 1967). All of the present work was carried out on the Black clays. These are developed over basic gneisses and consists of dark grey to black, heavy clays about 90-120cm deep. They are very sticky and plastic when wet but become hard and compact on drying when they also develop wide vertical cracks. Their cultivation poses serious problems because of the physical properties. It is considered that with the aid of irrigation and heavy machinery they could become highly productive with rice and sugarcane.

The Black clays carry medium grassland vegetation with Vetiveria fulvibarbis Trin, Stapf, as the major grass. In the south there is almost no woody vegetation, but scattered low shrubs appear as the Shai Hills are approached. Low stunted trees are frequent in the north. Forest and thickets occur on some of the basic gneiss inselbergs and along the borders of stream channels.

All laboratory work was conducted at Legon while most of the fieldwork was carried out at the University of Ghana Agricultural Research Station at Kpong and the Chinese Agricultural Mission Farm at

Dawhenya with a few observations at Ashiaman and Asutsuare. These places were selected on the basis of their proximity to Legon and the availability of rice fields.

The Kpong station was established in 1954 to conduct investigations on the Black clays under irrigation. The mean annual rainfall is about 118cm and the temperature ranges from 19°C to 35°C. Water for irrigation is pumped through a pipe line from the Volta River to a reservoir on the station.

The Dawhenya Farm was established in 1959 and has an annual rainfall of about 75cm and mean monthly temperature ranging from 21°C to 32°C. Water for irrigation is supplied by an earth dam across the Dechidaw River.

4. BIOLOGY OF THE PESTS

4.1 Materials and Methods

4.1.1 The Insects Studied

A total of four insect species were studied. These were Diopsis thoracica Westwood, Diopsis tenuipes Westwood, Diopsis ichneumonea Dahl. and Epilachna similis Muls. One other diopsid was occasionally collected from the field, but its immature stages could not be obtained. This species has not been identified and is referred to as Diopsis sp d. in the text. Diopsis tenuipes Westwood is synonymous with Diopsis apicalis Dalm. (Breniere, 1969). The identification of all the insect specimens was carried out at the British Museum of Natural History.

4.1.2 The Rice Varieties Used

Two rice varieties which were among the most widely grown in the country at the time of this study were used. They are SML Alupi and C4-63.

SML Alupi, which is a long-grain variety originating from Surinam was employed for all fieldwork at Kpong. It has a maturation period of 150 days from sowing to harvesting, is slightly photosensitive, of medium tillering and grows to a maximum height of about 135cm.

C4-63 is a medium-sized grain rice selected from crosses at the University of Philippines. It is day neutral, tillering capacity is moderately high, maximum height is approximately 105cm, and has a maturity period of about 125 days from sowing to harvesting. This variety was used for all fieldwork at Dawhenya, for feeding insects in the laboratory and for host preference and specificity tests at Legon.

4.1.3 Methods for the study of the Biology of the Insects

All insect specimens were reared in a laboratory in which the temperature range was 23 - 26°C (mean = 25°C) and the relative humidity range was 72 - 79% (mean = 75%). With the exception of D. tenuipes it was convenient to rear Diopsis eggs in petri dishes of 9cm diameter. Each dish was provided with a moist filter paper bed on which several eggs of the same species were put and the dish covered with its lid. The paper was subsequently moistened when necessary. Larval cannibalism was observed in D. tenuipes and the eggs were therefore reared singly in 1 x 5cm glass vials plugged with moist cotton wool. Eggs of E. similis were reared in the same way as those of D. tenuipes.

Several attempts to rear Diopsis larvae on cut rice stalks failed. Only the older larvae which were ready to pupate survived. It was therefore necessary to use potted rice plants. Each larva was put on a potted rice hill consisting of five to seven stalks. The pot and its contents were enclosed in 45 x 45 x 7cm cage with 0.2mm wire mesh on all the sides except the bottom which was wooden. The plants were watered when necessary. The larval instars of Diopsis were carefully dissected out of the stalks and examined each day. Larvae of E. similis were reared in 2.5 x 7.5cm glass vials. Fresh leaves of rice seedlings were provided everyday.

All pupae were reared in 2.5 x 7.5cm vials plugged with moist cotton wool.

Except where otherwise stated, potted rice seedlings covered with 10 x 15cm lantern glass globes were used as oviposition cages. The adult Diopsis species were fed on cotton wool soaked with dilute honey solution.

The descriptions and measurements of the various stages were based on both field-collected and laboratory-reared specimens. All measurements were made with a Becks binocular microscope fitted with an ocular micrometer and are expressed in millimeters. Definitions of the measurements are as follows:-

(a) Diopsis

Length of egg - total length measured dorsally

Width of egg - total width taken dorsally

Length of larva - total length, dorsally

Width of larva - maximum width measured on the fourth abdominal segment.

Length of cephalopharyngeal skeleton - total length from the base to the tip

Length of pupa - total length, dorsally.

Width of pupa - maximum width taken on the fourth segment

Length of Adult - total length, dorsally

Inter-orbital distance - total distance between the extreme borders of the two eyes of the adult.

(b) E. similis

Length of egg - total length from the base to the tip

Width of egg - maximum width measured at the base

Width of head capsule of larva - maximum width taken between the antennae

Length of larva - total length, dorsally

Width of larva - maximum width taken on the third abdominal segment

Length of pupa - total length, dorsally

Width of pupa - maximum width taken at the anterior end.

With the exception of adult Diopsis all measurements were made on ten specimens in each case. The mean and the standard deviations were calculated. The measurements of adult Diopsis were made on fifty specimens. All illustrations were made with the aid of a camera lucida.

4.2 Biology of *Diopsis* spp

4.2.1 Life Cycles

(a) *D. thoracica*

The incubation period for the eggs is 2-3 days with most of the eggs hatching on the third day after laying. The larvae emerged by making slits along the egg shell quite close to the anterior knob. Most larvae entered the rice stalk within about thrity minutes, usually moving down the inside of the terminal leaf sheath. They bored down to the base of the leaf to feed, cutting off the leaf which withers within 2-4 days, depending on the age of the rice. This symptom of withered terminal leaf is referred to as "deadheart". Sometimes the larvae fed above the primodia. In such cases the meristems were not killed, and although "deadheart" occured, the severed portions were displaced by new growth and the stalks survived. When the severed leaves began to decompose the larvae left the old stalks to attack new ones, choosing for their exit the slits between the sheaths and the terminal leaves. Occasionally some larvae got squeezed in the slits and died. The old larvae re-entered healthy stalks either within the hill it previously infested or chose a completely new hill.

Where larval feeding in the rice stalk occured after panicle initiation, the severing of the growing parts resulted in the death of the panicles; some of them did not emerge at all, and those that had already emerged did not produce grains. This condition of empty panicles is referred to as "whitehead".

There are three larval instars. The duration of these instars are given in table 1. In the laboratory the total larval life was 25 - 33 days (mean = 29 days) during which 3 - 6 stalks (mean = 4.8 stalks) were destroyed by each larva. When reared on six weeks old rice the larvae were observed to change stalks after every 4-9 days, stalk changing being more frequent as the larvae got older.

In most cases the mature larva selected a healthy stalk for pupation. In the field it was quite rare to find a pupa in a stalk with "deadheart" or "whitehead". Frequently pupae were found in hills which showed no visible sign of attack. This suggests that the larva might have been carried to the new hill by floating in the irrigation water. In most cases pupation occured in the outermost sheath of the stalk at a height of 3 - 8cm above soil level. The larva rested with its anterior end upwards and its ventral surface in the groove of the sheath. It then secreted a white foamy substance to plug the groove at the anterior end. This transformation required a few hours to complete. The shortest time observed in the laboratory was about three hours.

The duration of the pupa is shown in table 1. At eclosion, slits occured at the anterior end of the first segment of the pupa and along the lengths of the pair of lateral swellings on segments 1 - 3. As the insect forced its way out the plate was raised and broke either wholly or partially on the fourth segment. Where pupae were kept in glass vials it was noticed that the freshly emerged adults attempted to get out of the vials by squeezing themselves through the slits between the cotton wool and the glass.

(b) D. tenuipes

The eggs of D. tenuipes hatched within two days after laying and the larvae entered the rice stalk in the same way as D. thoracica. However, D. tenuipes continued to live and completed its life in the same stalk, feeding on the decaying material. In the field very young larvae were found in old decayed stalks. When both healthy and "dead-heart" stalks were offered to first instar larvae starved for 24 hours after emergence, it was found that both sources of food were acceptable and made no difference in the total duration of larval and pupal life.

The larvae pupated in the same stalk into which it bored. The pupae were usually found at the top of the sheath with their anterior ends upwards. Adult emergence occured in the same way as described for D. thoracica.

(c) D. ichneumonea

Only a few specimen of D. ichneumonea were available for study. The eggs hatched on the third day and larval behaviour was very similar to that of D. tenuipes. The larvae completed their life and pupated in the same stalk. Freshly emerged larvae could not, however, survive when offered only "deadheart" stalks. Like the other two species D. ichneumonea has three larval instars. The mode of adult emergence is the same as observed in D. thoracica.

Table 1 Summary of the Duration of the Immature stages of *Diopsis* spp

STAGE	DURATION (DAYS)		
	D. thoracica	D. tenuipes	D. ichneumonea
Egg	2.7[+] ± 0.2[++] (2-3)[+++]	2.0 ± 0.0 (2-2)	3.0 ± 0.0 (3-3)
Larva	29.0 ± 1.4 (25-33)	9.7 ± 0.7 (8-11)	13.6 ± 1.1 (11-16)
1st Instar	7.7 ± 0.9 (6-9)	2.6 ± 0.2 (2-3)	3.1 ± 0.8 (2-4)
2nd "	10.5 ± 0.7 (9-12)	2.4 ± 0.3 (2-3)	3.4 ± 0.5 (3-4)
3rd "	10.8 ± 0.6 (10-12)	4.7 ± 0.2 (4-5)	7.1 ± 0.6 (6-8)
Pupa	11.0 ± 0.8 (10-12)	7.3 ± 0.2 (7-8)	8.9 ± 0.4 (8-10)
Egg - Adult	42.7 + 1.8 (37-48)	19.0 ± 1.1 (17-21)	25.5 ± 1.4 (22-29)

\+ Mean

++ Standard deviation

+++ Range

4.2.2 Description of the Immature Stages

(a) *D. thoracica*

(i) Eggs (Fig. 2.A)

Length - 1.78[+] ± 0.08[++] (1.65 - 1.98)[+++]

Width - 0.42 ± 0.02 (0.38 - 0.45)

The eggs are cream white, but occasionally some are tainted black either partially or wholly. It has a thick shell which is ridged lengthwise. The middle is slightly swollen and the ventral side which is pressed to the support by a cementing gum is flattened. The two ends are raised and bear knobs. The anterior knob, partially separated from the rest of the egg by a crescent, is very flat and is about three times wider than long. The posterior knob is pointed.

(ii) Larvae

The larvae are generally white to cream and have a partially transparent skin. They are roughly cylindrical and consists of twelve segments the last of which is terminated by a forked tail. The two halves of the tail contain a pair of spiracles. The tail also bears short hairs at its extremity. The tracheal system is of the metapneustic form in the first instar but becomes amphineustic in the second and third instars. The pair of prothoracic spiracles are in the form of finger-like paddle. The mouthparts consist of a cephalopharyngeal

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\+ Mean of ten measurements (mm)
++ Standard deviation of mean
+++ Range of measurements.

skeleton made up of the following three parts:-

(1) a pair of curved but sharp mandibular sclerites

(2) a hypostomal screlite

(3) a pharyngeal sclerite (terminology of Imms, 1965).

<u>First Instar</u> (Fig.2.B)

Length	2.61 ± 0.31	(2.45 - 3.25)
Width	0.36 ± 0.04	(0.32 - 0.44)
Length of C.S.	0.21 ± 0.04	(0.17 - 0.28)

The first instar larva is whiter and more cylindrical than the mature larva. The prothoracic spiracles are absent, but the posterior spiracles are seen as a pair in the two halves of the tail. The tail ends are rounded and bear very fine hairs.

<u>Second Instar</u>

Length	11.81 ± 0.58	(10.53 - 12.68)
Width	1.63 ± 0.22	(1.21 - 1.87)
Length of C.S.	0.82 ± 0.07	(0.73 - 0.89)

The second instar is creamy white and more elongated than the first instar. The tracheal system is well developed and clearly seen through the skin. Both the prothoracic and posterior spiracles are present and are of light brown colour.

<u>Third Instar</u> (Fig.2. C)

Length	17.97 ± 0.33	(17.62 - 18.55)
Width	3.02 ± 0.06	(2.89 - 3.25)
Length of C.S.	1.18 ± 0.04	(1.00 - 1.24)

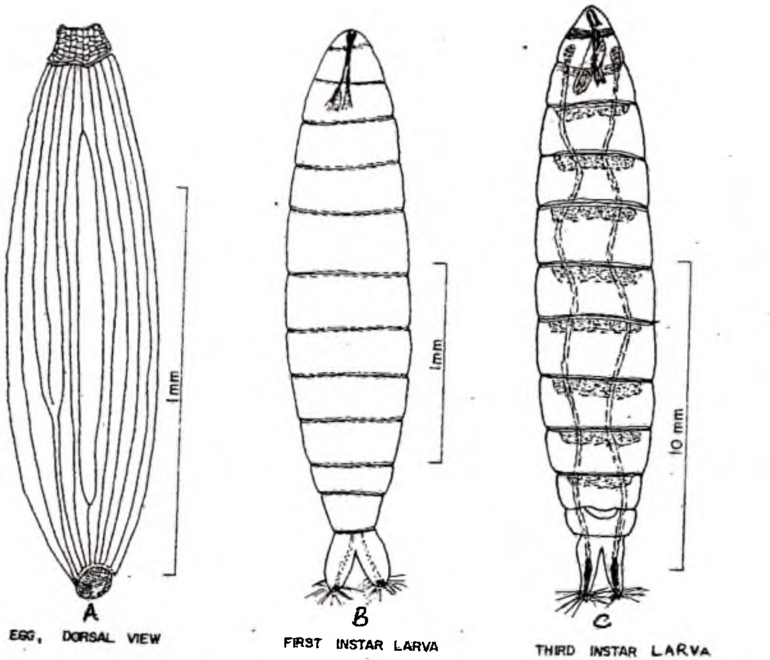
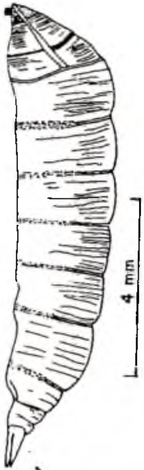
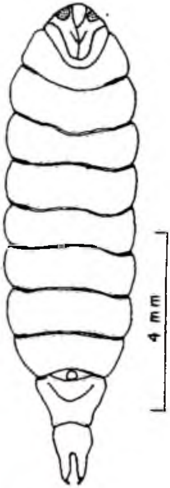


FIG. 2. DIOPSIS THORACICA



D

PUPA, LATERAL VIEW



E

PUPA, VENTRAL VIEW

It is very similar to the second instar in general appearance, but the cephalopharyngeal skeleton and the spiracles are deeply pigmented, assuming a deep brown colouration. The larva is pointed at both ends. The tail is elongated, thick at the base and has a sharp apex. The ring of hairs radiating from the end of each half of the tail are thicker than those of the first and second instars.

(iii) Pupae (Fig.2. D: E)

Length	10.81 ± 0.08	(10.69 - 10.90)
Width	2.71 ± 0.02	(2.68 - 2.73)

The pupae are of the exarate type. They may have a triangular or flattened appearance depending on the shape of the rice sheath in which pupation takes place. It has a brownish red colour dorsally with a cream ventral surface. The anterior end slopes dorsally and tapers to give a very small first segment. There are a total of twelve segments. The anterior spiracular tubercules appear as a pair of short knobs situated on the ventral surface of the first segment. The spiracles are deformed and appear as a ring of nipples at the end of the knobs. In some specimen the knobs are fallen off and scars are noticed in their positions.

Two pairs of lateral grooves appear on segments 1-3 and delimit two longitudinal swellings along the lateral aspects of these segments. The segmentation of the body is well marked, particularly towards the posterior end. A deep depression appears on the dorsal surface of the 11th segment. Ventrally this segment also bears two small circular depressions. The posterior spiracular tubercules are long and sharply pointed.

(b) *D. tenuipes*

(i) Eggs (Fig. 3.A)

Length	1.32 ± 0.03	(1.25 - 1.35)
Width	0.33 ± 0.02	(0.30 - 0.35)

The eggs are similar to those of *D. thoracica* in general appearance, but the anterior part is smaller in diameter than the posterior end. The anterior knob, which is elongated is separated from the rest of the egg by a slight depression. The posterior knob is rounded. Both knobs bear minute cup-shaped grooves.

(ii) Larvae

First Instar

Length	1.49 ± 0.01	(1.47 - 1.52)
Width	0.31 ± 0.03	(0.26 - 0.35)
Length of C.S.	0.25 ± 0.02	(0.22 - 0.28)

The first instar larva of *D. tenuipes* is quite similar to that of *D. thoracica*. It is white, cylindrical and has a forked tail. The prothoracic spiracles are absent but the posterior spiracles are present. The tail is rounded and bear minute hairs. These hairs are forked at their extremities.

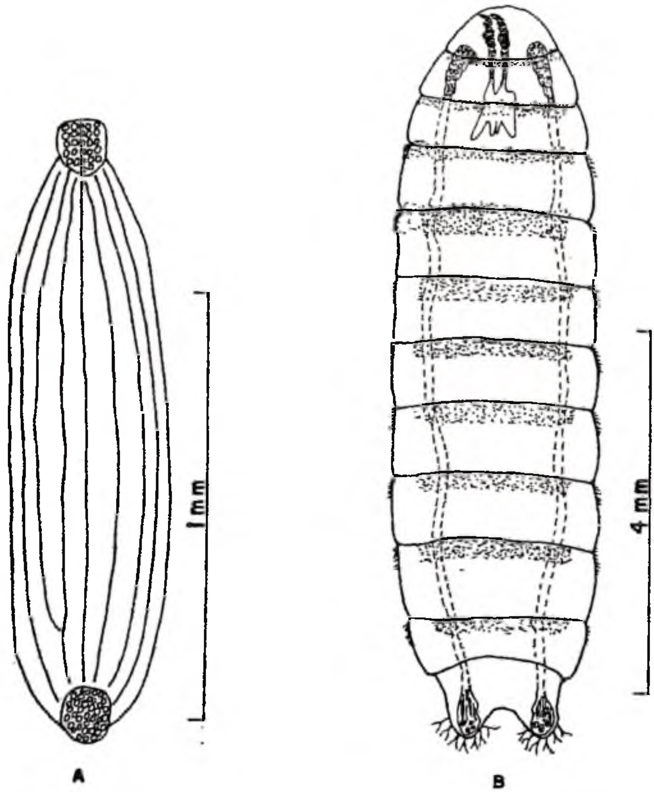
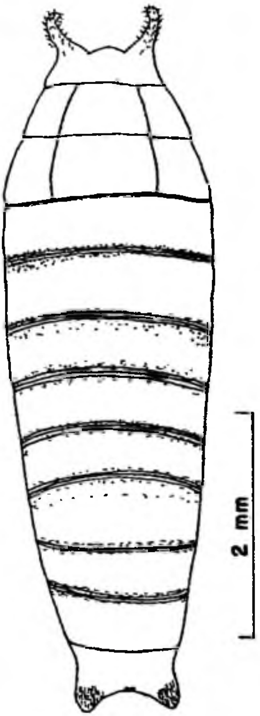


FIG. 3. DIOPSIS TENUIPES

A. EGG, DORSAL VIEW

B. THIRD INSTAR LARVA

C. PUPA, DORSAL VIEW



c

Second Instar

Length	4.59 ± 0.51	(4.05 - 5.68)
Width	0.53 ± 0.04	(0.48 - 0.62)
Length of C.S.	0.82 ± 0.03	(0.77 - 0.96)

The second instar resembles the first instar, but it is more cylindrical and has both prothoracic and posterior spiracles. The tail end is blunt and the hairs at the end of the tail are forked but thicker than in the first instar.

Third Instar (Fig. 3.B)

Length	8.44 ± 0.05	(8.36 - 8.52)
Width	1.53 ± 0.10	(1.42 - 1.68)
Length of C.S.	1.08 ± 0.03	(1.04 - 1.13)

The general structure is as found in the second instar, but the larva has a stumpy appearance and is almost cylindrical throughout its length. The tracheal trunks and the spiracles are similar to those D. thoracica. The tail is very short and cone-shaped with blunt ends. The hairs at the end of the tail are thick and forked at their extremities.

(iii) Pupae (Fig. 3.C)

Length	5.80 ± 0.06	(5.71 - 6.00)
Width	1.65 ± 0.08	(1.60 - 1.70)

The pupa is of the exarate form. It is cylindrical, pointed at both ends and white in colour. The anterior and posterior tubercules are, however, dark. There are twelve segments, but the segmentation is often difficult to see due to the presence of a white powdery substance. The first three segments gradually increase in width posteriorly to give a triangular appearance to the dorsal aspect of the thorax which also slopes anteriorly. Two subdorsal grooves are found on segments 2-3 and divide the dorsal aspect of these segments into three parts. The pair of anterior spiracular tubercules are long and are placed dorso-laterally on the first segment. The spiracles appear as nipples on the tubercules. The posterior tubercules are cylindrical, stumpy and blunt at the ends.

(c) D. ichneumonea

(i) Eggs (Fig. 4.A)

Length	1.89 ± 0.02	(1.85 - 1.95)
Width	0.43 ± 0.04	(0.40 - 0.45)

The eggs are very similiar to those of D. thoracica but they are longer. The anterior knob is triangular while the posterior knob is rounded. Both knobs are preceded by minute nipples.

(ii) Larvae

First Instar

Length	1.61 ± 0.06	(1.58 - 1.68)
Width	0.32 ± 0.02	(0.29 - 0.34)
Length of C.S.	0.19 ± 0.01	(0.17 - 0.20)

The larva has a general structure quite similar to the larvae of

D. thoracica and *D. tenuipes*. The prothoracic spiracles are absent, but the posterior spiracles are present. The tail is cylindrical and bear fine hairs which are forked at their extremities as found in *D. tenuipes*.

Second Instar

Length	8.08 ± 0.24	(7.83 - 8.96)
Width	0.98 ± 0.04	(0.90 - 1.17)
Length of C.S.	0.61 ± 0.05	(0.52 - 0.68)

The structure is as found in the first instar, but prothoracic spiracles are present. The hairs at the end of the tail are very thick and forked.

Third Instar (Fig. 4.B)

Length	12.97 ± 0.21	(12.80 - 13.15)
Width	2.01 ± 0.04	(1.95 - 2.10)
Length of C.S.	0.79 ± 0.01	(0.77 - 0.81)

The third instar is creamy white. It is cylindrical only from segments 4-12 and is pointed in the anterior direction. The spiracles are similar to those of *D. tenuipes*. The tail is longer than that of *D. tenuipes* and the two halves are cylindrical with blunt ends. The hairs at the end of the tail are thick and forked at their extremities as found in *D. tenuipes*.

(iii) Pupae (Fig. 4.C)

Length	7.86 ± 0.06	(7.80 - 7.91)
Width	1.99 ± 0.07	(1.90 - 2.10)

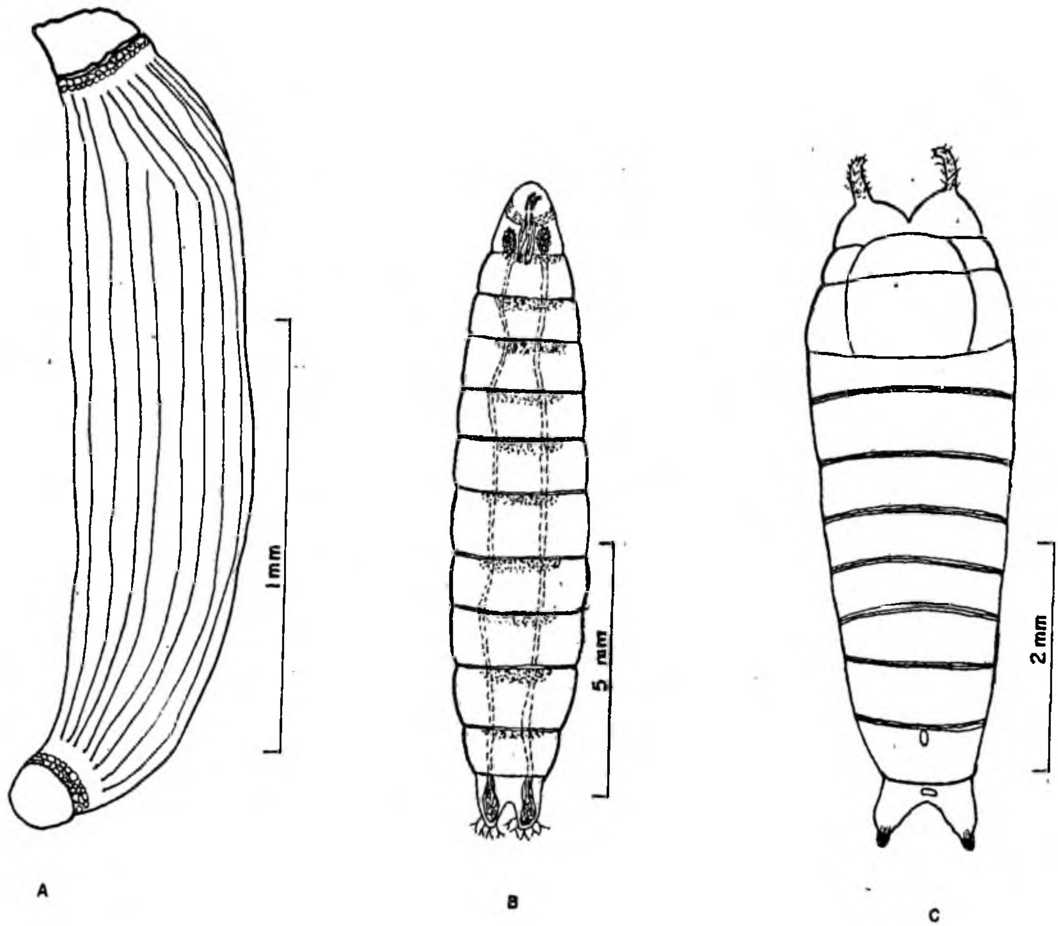


FIG. 4. DIOPSIS ICHNEUMONEA

A. EGG, LATERAL VIEW

B. THIRD INSTAR LARVA

C. PUPA, DORSAL VIEW

The pupa is subcylindrical and white with a powdery substance. The first three segments slope anteriorly as in _D. tenuipes_. There is also a pair of subdorsal grooves on segments 2 - 3. The anterior end of the first segment is notched. The pair of anterior spiracular tubercules are in the same position as in _D. tenuipes_ and bear nipples as well. The posterior spiracular tubercules are conical at their bases but are terminated by short tubular parts.

4.2.3 Description of the Adults

All the _Diopsis_ species recorded in this study appear reddish brown in colour when viewed dorsally. The ventral surface of the abdomen is cream or orange depending on the species. The thorax is black in all the species.

The head is triangular when viewed dorsally and its lateral sides have two long eye stalks bearing the pair of compound eyes. Quite close to the eyes is a pair of 3- segmented antennae with long bristles. The ocelli are arranged triangularly on the head. Ventrally the head bears a deep groove and a pair of short but sharp spines. The mouthparts are the sucking type and when the insect is feeding the proboscis is seen as an elongated grooved structure with a circular oral disc.

The cervix is short and is followed by a rounded thorax which bears three pairs of hairy jointed legs each with six tarsal segments. The second and third femora have very sharp apical spines. The pleurotergite bears a pair of short spines and quite close to these are the pair of halteres. There is a scutellum towards the posterior end of the thorax and this bears a pair of long sharp spines. The wing venation is reduced. The costa is complete. R_{2+3}, R_{4+5} and M_{1+2} reach the margin of the wing. The cubitus and anal veins are absent.

The abdomen consists of four segments. It is very slender at the anterior end and enlarges towards the posterior extremity.

(a) D. thoracica (Plate 1.A)

Body length of both sexes	8.09 ± 0.19	(7.50–8.50)
Inter-orbital distance of male	13.18 ± 0.61	(12.00–14.20)
Inter-orbital distance of female	11.69 ± 0.40	(11.00–12.25)

This species exhibit sexual dimorphism with regard to the inter orbital distance. When measurements were taken on the inter orbital distance of fifty males and fifty females collected from the field, the mean distance was found to be 13.18mm and 11.69mm respectively. A t-test showed that the difference was highly significant ($P = 0.01$) (Appendix 3).

The adult D. thoracica has a general reddish colouration but the dorsal aspect of the posterior end of the abdomen is deeper red. The scutellum is also red with red scutellar spines bearing numerous hairs. The abdomen is bell-shaped, has a cream ventral surface, and is covered

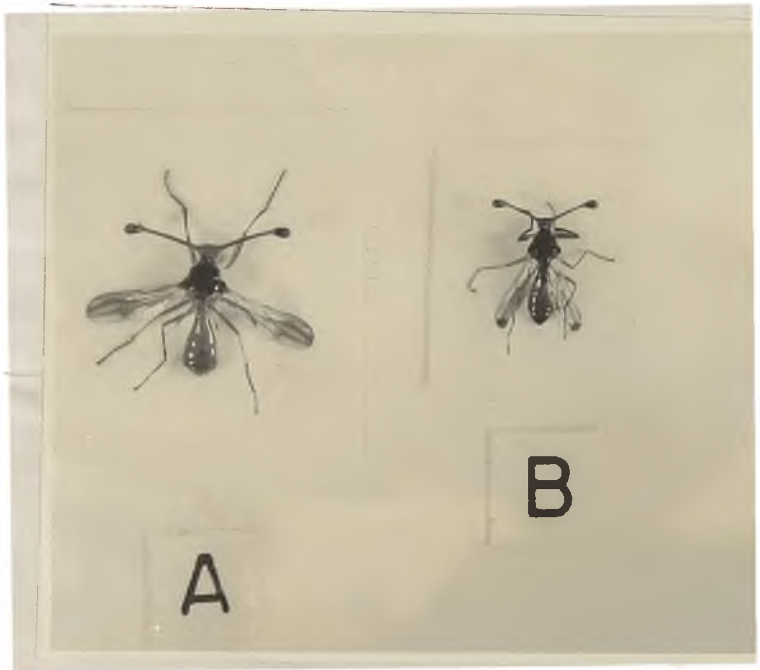


PLATE 1. Diopsis spp

A - D. thoraciaa

B - D. tenuipes

C - D. ichneumonea


C

with thick hairs. The first femora are not swollen and the wings have a light brown colour with no spots.

(b) D. tenuipes (Plate 1.B)

Body length of both sexes 7.36 ± 0.07 (6.60-7.90)

Inter orbital distance of both sexes 7.72±0.18 (7.50-7.93)

This species exhibit no sexual dimorphism with regard to the inter orbital distance. It has a reddish appearance and the dorsal aspect of the extremity of the abdomen is deep red as found in D. thoracica. The ventral surface of the abdomen is cream but often assumes an orange colour in the gravid females. It differs from D. thoracica by possessing a black scutellum. The scutellar spines are red with dark apices. The abdomen is less hairy, the first femora are not swollen, but the wings have black spots at their apices.

(c) D. ichneumonea (Plate 1.C)

Body length of both sexes 6.28 ± 0.05 (6.20 - 6.39)

Inter orbital distance of both sexes 4.36 ± 0.07 (4.25 - 4.45)

Like D. tenuipes this species exhibits no sexual dimorphism with regard to the inter orbital distance. Its size is quite close to that of D. tenuipes but the eye stalks are very short. Its colour is much similar to that of D. thoracica and D. tenuipes but in contrast to these two species the dorsal aspect of the tip of the abdomen is dark. The scutellum is black and the scutellar spines are yellowish. The first femora are swollen and the wings have pre-apical black spots.

(d) Diopsis sp d.

Only a few specimens were found in the field. It resembles D. thoracica in several aspects but exhibits great variations in the body size. The acutellum is dark and the abdomen is less hairy. Like D. ichneumonea it has a swollen first femora, but the wings have no black spots.

4.2.4 Keys for the Identification of the Developmental Stages of Diopsis spp

(i) Key for the identification of eggs of Diopsis

1. Egg length exceeding 1.50mm 2

\- Egg length less than 1.50mm 3

2. Terminal knobs preceded by nipples; anterior knob traingular; posterior knob rounded ...... Diopsis ichneumonea Dahl.

\- Terminal knobs not preceded by nipples; anterior knob flat and wider than long, posterior knob pointed .... Diopsis thoracica Westwood.

3. Terminal knobs not preceded by nipples; anterior knob longer than wide; posterior knob rounded ...... Diopsis tenuipes Westwood.

(ii) Key for the Identification of Third Instar Larvae of Diopsis

1. Tail with blunt ends 2

\- Tail elongated, thick at the base and with a sharp apex;

Body length 17 - 19mm .... Diopsis thoracica Westwood.

2. Body cylindrical throughout the length, not sharply pointed anteriorly; tail cone-shaped; Body length 7 - 9mm .... Diopsis tenuipes Westwood.

— Body cylindrical only from segments 4 - 12, sharply pointed anteriorly; tail cylindrical; Body length 11 - 14mm .... Diopsis ichneumonea Dahl.

(iii) Key for the Identification of the Pupae of Diopsis

1. Pupa white in colour 2

— Pupa brownish red dorsally, cream ventrally; anterior spiracular tubercules situated ventrally; posterior spiracular tubercules with very sharp ends; length 10 - 11mm .... Diopsis thoracica Westwood.

2. Anterior end of first segment notched; anterior spiracular tubercules situated dorso-laterally; posterior spiracular tubercules conical and terminated by a short tubular part; length 7 - 8mm ...... Diopsis ichneumonea Dahl.

— Anterior end of first segment not notched; anterior spiracular tubercules situated dorso-laterally; posterior spiracular tubercules cylindrical with a blunt end; length 5 - 6mm .... Diopsis tenuipes Westwood.

(iv) Kev for the Identification of Adult *Diopsis*

1. First femora swollen 2

- First femora not swellen 3

2. Pair of wings with one black sport each, spots sub-apical .... *Diopsis ichneumonea* Dahl.

- Wings without any black spot .... *Diopsis* sp d.

3. Pair of wings with one black spot each, spots apical; scutellar spines with black apices .... *Diopsis tenuipes* Westwood.

- Wings without any black spot; scutellar spines reddish throughout their lengths; abdomen very hairy .... *Diopsis thoracica* Westwood.

4.2.5 Oviposition Habits

(a) *D. thoracica*

Mating could not be observed. The preoviposition period lasted for 14 - 17 days (mean = 15.4 days). Descamps (1957) observed that the female copulates several times in her life time.

The eggs were laid singly around the middle of the upper surface of the subterminal leaves, often in the grooves of the midrib. A few eggs were laid on the undersurface of the leaves. Sometimes two eggs were found together, lying parallel to each other. On young plants almost all the eggs were confined to the leaves. It was observed in the field that when the rice reached a height of about 60cm most of the eggs were laid on the stalk about 5 - 20cm above soil level.

In the laboratory the total number of eggs laid by a single female ranged from twenty-six to fourty-three with an average of thirty-two. This was spread over a period of one week. Up to fifteen eggs could be laid by a single female in a day, but it was more usual to observe 6 - 10 eggs per day. Sometimes egg laying was interrupted by a day during which no oviposition occured. Most of the females died 1 - 3 days after the last oviposition. When such insects were dissected they were found to contain 5 - 15 eggs, for example the female that laid fourty-three eggs contained six eggs after death. It was observed that more eggs were laid between the hours of 9.00 a.m. - 12.00 p.m. and 3.00 p.m. - 6.00 p.m.

(b) D. tenuipes

Unlike D. thoracica, D. tenuipes chose infested stalks for oviposition. In cages with both healthy and "deadheart" stalks the latter always received more eggs. Most of the eggs were laid at the bases of the subterminal leaves in the grooves of the midveins, very close to the ligules. They were laid singly but up to five eggs were occassionally found together at the same spot.

In the field it was common to find eggs of D. tenuipes laid around cuts made on the rice stalks by rodents or the entry holes of lepidopterous borers. Sometimes such holes were plugged with the eggs of

D. tenuipes.

The maximum number of eggs laid by caged insects was found to be twenty-seven per female, spread over twelve days, with 1 - 3 eggs a day.

(c) D. ichneumonea

The egg laying behaviour could not be studied in detail, since only a few specimen were available. The eggs were deposited in the grooves of the subterminal leaves of healthy stalks, around the middle of the upper surface.

4.3 Biology of Epilachna similis Muls.

4.3.1 Life Cycle

The eggs hatch in 4 - 5 days after laying. The larvae emerged by making slits at the apices of the eggs. The young larvae fed in groups mostly on the lower surface of young rice leaves leaving the upper epidermis. The later instar dispersed to other rice plants to feed. The feeding caused death of the leaves and in severe infestation the whole plant died. Old rice leaves were scarcely attacked. There are four larval instars and their durations are summarized in table 2.

When ready to pupate the larva fixed itself often to the under-surface of the leaf by the anal end. Pupation lasted four days. The adult emerged by breaking the line along the posterior end of the pupal pronotum.

The adult fed on rice leaves in the same way as the larvae.

Table 2 Summary of the duration of the immature stages of *E. similis*

STAGE	DURATION IN DAYS (mean) (SD)	(range)
Egg	4.3 ± 0.3	(4 - 5)
Larva	14.6 ± 1.1	(12 - 17)
1st instar	3.6 ± 0.2	(3 - 4)
2nd "	3.2 ± 0.4	(2 - 4)
3rd "	3.4 ± 0.2	(3 - 4)
4th "	4.4 ± 0.3	(4 - 5)
Pupa	4.0 ± 0.0	(4 - 4)
Egg - Adult	22.9 ± 1.6	20 - 26

4.3.2 Description of the Immature stages of *Epilachna similis* Muls

(i) Eggs (Plate 2.A)

Length 1.20 ± 0.02 (1.18 - 1.28)

Width 0.42 ± 0.02 (0.37 - 0.45)

The eggs are cone-shaped and are laid mostly on the lower surface of rice leaves in batches of 15 - 55; mean = 36. When freshly laid they are bright yellow in colour but turn dark as they approach eclosion.

They are very shiny but have minute brown nipples all over the surface. These nipples increase in size towards the tip of the egg; this gives the extremities of the eggs a brown colouration.

(ii) Larvae

The four larval instars have the same general appearance.

The larvae have a porcupine-like appearance, the body being clothed with spines. The body is oval, widest at the third abdominal segment and narrower posteriorly than anteriorly. It is convex on the dorsal surface and almost flat on the ventral aspect.

The head is heavily sclerotized and deeply pigmented. It is connected to the thorax by a moderately long cervix. The epicranial suture is Y - shaped and indicated by a lighter colouration. The arms of the two frontal sutures run almost straight from the anterior end of the coronal suture to the bases of the antennae. There are three ocelli on either side of the head. These are arranged triangularly at the bases of the antennae. The antenna is 3- segmented with a well developed base. The clypeus bears a few setae on the lateral margins. The maxilla bears a long 3- segmented maxillary palpus.

The thorax bears three segments, the prothorax being longer but smaller in diameter than either of the other two segments. The mesothorax and the metathorax are similar in shape. The prothorax bears two pairs of scoli while the mesothorax and the metathorax bear three pairs each, the pairs being symmetrically arranged on either side of the median ecdysial line on all the three segments. Only the mesothorax bears a pair of spiracles. These are situated dorsally at the anterio-lateral part of the segment. Each thoracic segment bears a pair of legs which are all similar. Each leg bears setae and is terminated by a claw.

The abdomen consists of ten segments. Each of the first eight segments bears three pairs of scoli and a pair of spiracles. Kapur (1950) has assigned names to the three pairs of scoli on the thoracic and abdominal segments. He referred to the scolus near the mid-dorsal line as the dorsal scolus, next to it is the subdorsal scolus and the third, situated farthest from the mid-dorsal line and usually on the lateral margin, is called the dorso-lateral scolus (Fig.5). Each abdominal spiracle is situated anterio-lateral relative to the base of the sub-dorsal scolus. The ninth segment is semi-circular in shape. The tenth segment is short, whitish, directed downwards and forked at its end. Segments 9 and 10 bear short setae on their ventral surfaces.

The four instars vary in size, colour, and number of spines per scolus.

<u>First Instar</u> (Fig.6.A)

Width of head capsule	0.42 ± 0.02 (0.40 - 0.45)
Length of body	2.44 ± 0.03 (2.40 - 2.48)
Width of body	0.60 - 0.80 mm; mean = 0.67mm.

The larva is grey on the dorsal surface, light orange on the ven-

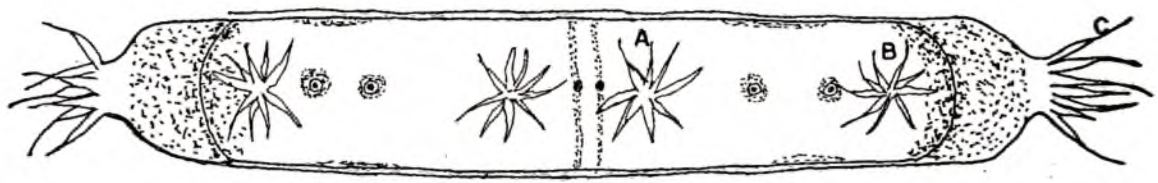


FIG. 5. ABDOMINAL SEGMENT OF EPILACHNA SIMILIS SHOWING THE POSITIONS OF THE SCOLI (DIAGRAMATIC).

A. DORSAL SCOLUS

B. SUBDORSAL SCOLUS

C. DORSO – LATERAL SCOLUS

tral surface and has a brown head. The scoli on the prothorax bear 4 - 6 spines each. The mesothoracic and metathoracic scoli bear three spines each except the dorso-lateral scoli which bear only one spine each. The abdominal scoli bear 2 - 3 spines each but the dorso-lateral scoli bear only one spine each.

<u>Second Instar</u>

Width of head capsule	0.62 $\pm$ 0.03	(0.58 - 0.69)
Length of body	2.95 $\pm$ 0.12	(2.80 - 3.05)
Width of body	1.10 $\pm$ 0.09	(0.90 - 1.41)

The larva is deep grey and more pigmented than the first instar. All other features are quite similar to the first instar. The prothoracic scoli have 4 - 7 spines each while the meso~~thoracic~~ and metathoracic 4 - 6 spines each. The dorso-lateral scoli of the thoracic and abdominal segments bear one spine each.

<u>Third Instar</u>

Width of head capsule	0.76 $\pm$ 0.02	(0.70 - 0.79)
Length of body	4.43 $\pm$ 0.02	(4.40 - 4.50)
Width of body	1.37 $\pm$ 0.04	(1.31 - 1.43)

The larva is very deep grey dorsally with a bright orange ventral surface. The other features are again quite similar to those found in the first and second instars. The scoli on all the thoracic segments bear 8 - 10 spines each except the dorso-lateral scoli which have 4 - 6 spines each. The abdominal scoli bear 4 - 6 spines but the dorso-lateral scoli bear 2 - 4 spines each.

Fourth Instar (Fig.6.B; Plate 2B)

Width of head capsule	1.11 ± 0.05	(1.03 - 1.17)
Length of body	7.27 ± 0.03	(7.05 - 7.35)
Width of body	2.78 ± 0.04	(2.70 - 2.83)

This is the only instar with a bright yellow colour on both the dorsal and ventral surfaces. The thoracic scoli bear 8 - 13 spines each while the abdominal scoli have 6 - 10 spines each. All dorso-lateral scoli bear 4 - 10 spines each.

(iii) Pupa (Fig.6.C; Plate 2C)

Length	6.64 ± 0.14	(6.45 - 6.98)
Width	3.46 ± 0.25	(3.10 - 3.85)

The pupa is of the exarate form. It is broad at the anterior end, pointed at the posterior end and convex on the dorsal aspect with a flat ventral surface. The larval exuviae are pushed back to the anal extremity exposing the head, pronotum and 4 - 7 pupal segments. When freshly formed the exposed parts are yellowish, but later turn cream and finally black before emergence of the adult.

The developing head is bent downwards leaving the pronotum at the anterior extremity. Ventrally the head, antenae, compound eyes and legs are seen folded together. The pair of wings are triangular in shape and are arranged along the lateral sides of the body.

Dorsally each exposed segment bears a pair of round pigmentation

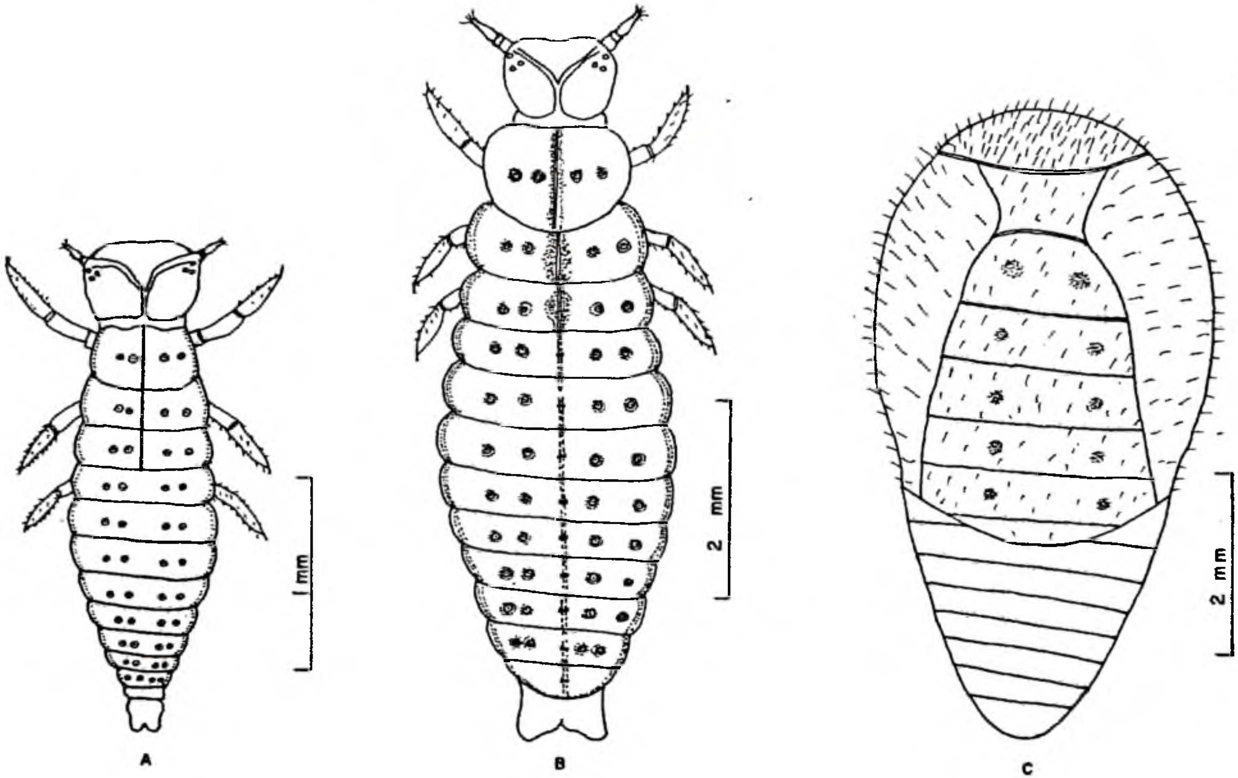


FIG. 6. EPILACHNA SIMILIS

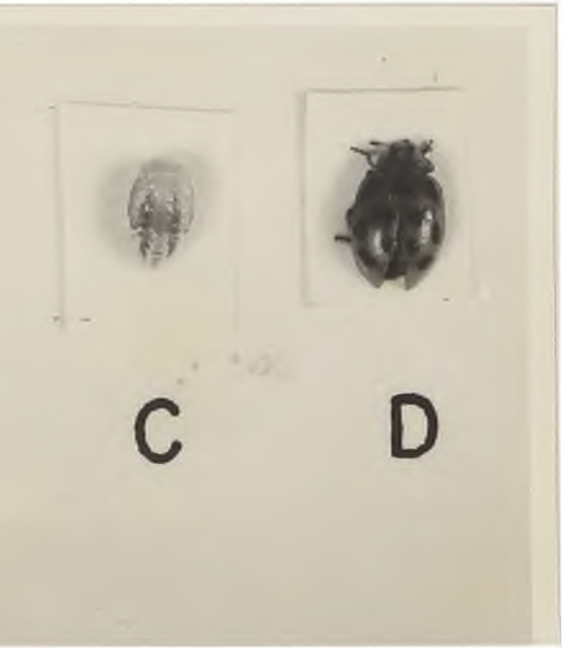
A. FIRST INSTAR LARVA

B. FOURTH INSTAR LARVA

C. PUPA.

(LARVAE DRAWN WITHOUT THE SCOLI)

PLATE 2



EPILACHNA SIMILIS

A - Eggs

B - Fourth Instar Larva

C - Pupa

D - Adult

along the subdorsal lines. The exposed parts of the body bear hairs which are more pronounced on the pronotum and wings.

4.3.3. Key for the Identification of Larval Instars of *E. similis*

1. Dorso-lateral scoli of mesothorax, metathorax and abdominal segments with only one spine each 2
- Dorso-lateral scoli of mesothorax, metathorax and abdominal segments with two or more spines 3
2. Head capsule width not exceeding 0.50mm; bases of scoli swollen .... First Instar.
- Head capsule width exceeding 0.50mm; bases of scoli not swollen .... Second Instar.
3. Larva of deep grey colour; head capsule width 0.7 - 0.8mm; dorso-lateral scoli of mesothorax, metathorax, and abdominal segments with 2 - 6 spines each .... Third Instar.
- Larva of bright yellow colour; head capsule width 1 - 2mm; dorso-lateral scoli of mesothorax, metathorax, and abdominal segments with 4 - 10 spines each .... Fourth Instar.

4.3.4 Description of Adult *E. similis* (Plate 2.D)

Width of head	1.09 ± 0.04 (1.00 - 1.32)
Length of body	5.97 ± 0.05 (5.78 - 6.05)

The adult is reddish brown all over the body. It is convex on the dorsal surface and flat ventrally.

The head is very small and is partially concealed by the pronotum. The mouthparts which are of the biting type are not so conspicuous. The mandibles are very short, dark at the edges and possess many teeth. The labium is very small with comparatively long 3 - segmented labial palps. The maxilla is ventral to the mandibles and lateral to the labium. It is cylindrical and bears a 3-segmented club-shaped maxillary palp. The antenna bears eleven segments. It is clavate and slightly geniculate. A pair of black compound eyes are situated just posterior to the antennae.

The prothorax is mavable and larger than the mesothorax or the metathorax. The legs are short and usually folded under the body.

4.3.5 Oviposition Habits

Copulation occurs any time during the day and each female mates several times in her life time. The preoviposition period is 4 - 8 days (mean = 5.8 days)

When egg-laying began it continued without interruption with one batch of egg a day for 2 - 3 weeks. Beyond this period breaks of 1 - 5 days were noticed. Occasionally, two batches of eggs were laid on the same day, but the maximum number of eggs per day never exceeded sixty. The total number of egg batches laid varied from 10 - 40 per female. The number of eggs per batch increased with subsequent oviposition up to a peak of 46 and then dropped gradually. The total number of eggs laid varied from 229 to 797 per mated female. The individual that produced 797 eggs laid them in 40 batches over a period of 48 days.

The eggs are laid with a dark brown cementing substance which holds the batch to the leaf. Unmated females laid eggs but these were in smaller batches and were scattered since they have little or no cementing substance. Such eggs shrivelled and did not hatch. The unmated females stopped laying after a few days. It was observed that some mated females did not lay eggs at all or laid for a few days and stopped. Such individuals stopped feeding and hid themselves between the rice stalks. Some insects remained in this state for as long as four months.

Mating is quite frequent when the sexes are paired. Where females were allowed to mate only once they produced fertile eggs for about a month, but thereaster all eggs laid were infertile.

4.4 Discussion

4.4.1 Diopsis spp

The inability to rear Diopsis larvae on cut rice stalks is a serious limitation to the mass rearing of the species. The use of potted rice seedlings is cumbersome. There is therefore the need to develop a suitable artificial rearing method.

Generally, the descriptions and the biology of these insects agree favourably with the observations of Descamps (1957a; b). In the present work additional information has been provided by describing the different larval instars of the three species.

Based on the mode of feeding Descamps (1957a) has divided the larvae of Diopsis spp into two major groups, viz:-

1. Those exhibiting obligatory phytophagy
2. Those exhibiting optional phytophagy.

Obligatory phytophagy is further subdivided into two:-

(a) Larvae feeding only on living stalks and which cannot be maintained at any stage in their life on decaying vegetable matter. Into this group can be placed D. thoracica.

(b) Larvae feeding on living stalks for the first few days and which can later thrive on decomposing vegetable matter. The species in this subgroup include D. ichneumonea.

Optional phytophagy is exhibited by D. tenuipes. The larva of this species can exist in three different ways:-

(a) As phytophagous larva in the same way as D. ichneumonea. This often occurs when the eggs are laid on healthy stalks.

(b) As a saprophyte, when the eggs are laid on already attached plants. This is the most predominant mode of larval life in the field.

(c) As a predator on other larvae which it comes into contact with.

The ability to feed on several rice stalks during the larval life makes D. thoracica very destructive to the rice crop. The larval life is comparatively longer than D. tenuipes and D. ichneumonea and as much as six stalks can be destroyed by a single larva. The ability to float in the irrigation water means that every available rice hill could be attacked.

The mechanism of plugging the groove above the anterior end of the pupa with a white foamy substance is probably in defence against natural enemies. It was observed that the pupae are heavily parasitized in the field.

Unlike D. thoracica, the larvae of D. tenuipes and D. ichneumonea complete their life in one stalk and therefore destroy fewer stalks. The larval cannibalism of D. tenuipes observed in the laboratory has also been reported by Descamps (1957b). He found in the field, larvae of D. tenuipes feeding on each other and on young larvae of other pests such as D. thoracica, Antherigona spp and Sesamia spp.

4.4.2 Epilachna similis

Apart from the short notes on the life cycle of E. similis provided by a few earlier workers such as Maxwell-Lefroy (1909), Smithers (1957) and Schmutter (1969), there appears to be no detailed study of this species. The descriptions of the various stages of this insect can only be compared with the general account on the subfamily Epilachninae (Coleoptera; Coccinellidae) given by Kapur (1950). Such a comparison does not reveal any marked deviation from the general observations on the subfamily.

It has been pointed out that many females of E. similis did not lay eggs or laid eggs for a short time and then withdrew from all forms of activity to hide in between the rice stalks. This behaviour has already been described by Maxwell-Lefroy (1909) as a form of hibernation the purpose of which is to await better conditions for egg laying. He also points out that egg laying is more prolific when the adults are well fed.

5. SEASONAL POPULATION CHANGES

5.1 Materials and Methods

With irrigation facilities double cropping per year is the practice of rice cultivation in the Accra Plains. These seasons are usually September to February and March to July. However, to achieve a continuous cropping cycle for the purpose of this tudy tripple cropping was done at both Kpong and Dawhenya for systematic sampling from March 1971 to April 1972. The two rice farms follow different cultural practices but at far as possible, a uniform method was adopted for the sampling.

At each cropping an 0.1 hectar plot of size 45 metres x 25 metres was chosen. At Kpong the rice seeds were drilled at a rate of approximately 90 kilograms per hectare and the first sampling was done two weeks after germination. At Dawhenya the seeds were nursed for twenty days and then transplanted at a spacing of 25cm x 25cm inches with four seedlings per point. Sampling was started two weeks after transplanting. On both farms subsequent samplings were carried out at regular intervals of fourteen days until the grains were fully ripe.

Sampling for eggs, larvae and pupae of Diopsis spp was done by removing fifty rice hills from the plot on each sampling day. Leaving out a border of 1 metre the hill closest to the toe after every tenth pace (one pace was approximately 50cm) in either direction was sampled. Where a hill was missing the next was selected. This method gave 10 hills length wise and 5 hills breadthwise. At each sampling the heights of 20 plants, measured from the soil level to the highest point, were taken and the mean calculated.

The same plots were used to sample for E. similis. This was done by examining 50 rice hills, selected at 10 paces in either direction, for eggs, larvae and pupae.

To get an estimate of adult Diopsis spp and E. similis populations net sweeping was done. Such sweepings were carried out at 9.00 am on each visit. Previous sampling had shown that more insects are caught at this time of the day, when they are very active. Muslin nets of 40cm diameter and a depth of 60cm were used. There were 100 sweeps per plot, counting as one sweep each swing from right to left and back. These sweeps were taken along the width of the plot after every ten paces. The nets were emptied after every tenth sweep. In the laboratory the species were separated and sexed by examination of the genetalia.

On the day of sampling the rice hills were examined in the laboratory and hill and stalk infestations were recorded. These were expressed as percentages. The stalks were dissected to record the eggs, larvae and pupae of Diopsis spp. These were separated into species with the aid of a binocular microscope. Distinction was made between infestations caused by diopsid and lepidopterous borers. In infestations due to lepidopterous borers frass is always present on the stalks; diopsid borers never show such a symptom. Rice hills or stalks which had "deadhearts", "whiteheads" or contained larvae or pupae, but had no visible sign of attack were recorded as infested.

At harvest 50 rice hills per plot were sampled to record the number of panicles and "whiteheads". From these the percentage panicle and "whitehead" were calculated.

5.2 Seasonality of Diopsis spp.

Stalk infestation by lepidopterous borers at both Kpong and Dawhenya remained very low and never exceeded 2.9%. In contrast to this, infestation by diopsids reached a maximum of 48.4% at Dawhenya. The lepidopterous borers recorded were Sesamia spp. (Lepidoptera; noctuidae), Chilo spp (Lepidoptera; pyralidae) and Maliarpha separatella Rag. (Lepidoptera; pyralidae).

The results of the systematic samplings are shown in tables 3 - 14 and figs. 7 - 12. The infestation followed a similar trend at both Kpong and Dawhenya. The first samplings at two weeks after transplanting never failed to show infestation. Infestation then rose sharply and reached a peak when the plants were 58 - 72 days old. The persentage "whiteheads" for the three croppings are tabulated for comparisons with the maximum infestations in table 15. On the whole more rice stalks were damaged in the major rainy season.

The most dominant Diopsis species was D. thoracica followed by D. tenuipes; D. ichneumonea and Diopsis sp. d were very rare. Figs. 8

Table 3 Diopsis infestation on rice at Kpong

March - June 1971

Date	Age of Rice (Days)	Mean Height (cm)	Mean No. of stalks per hill	% Infestation		Diopsis Species					
				Hill	Stalk	D. thoracica			D. tenuipes		
						E*	L	P	E	L	P
11-3-71	17	26.1	2.0	8.3	4.0	3	1	-	-	-	-
25-3-71	31	36.5	2.9	20.0	11.8	5	4	-	2	-	-
8-4-71	45	50.5	3.2	56.0	28.8	13	7	-	2	-	-
22-4-71	59	65.2	5.2	58.0	22.0	3	10	2	3	3	-
6-5-71	73	72.8	6.8	54.0	18.2	2	6	8	-	2	2
20-5-71	87	106.4	6.9	52.0	13.3	-	3	7	-	3	3
3-6-71	101	113.8	6.5	54.0	15.2	-	1	2	-	1	5
17-6-71	115	126.8	6.1	24.0	5.4	-	2	2	-	3	2
Total	-	-	-	-	-	26	34	21	7	12	12

* E = Eggs, L = Larvae, P = Pupae

Table 4 Diopsis infestation on rice at Kpong

July - September 1971

Date	Age of Rice (Days)	Mean Height (cm)	Mean No. of stalks per hill	% Infestation		Diopsis Species					
				Hill	Stalk	D. thoracica			D. tenuipes		
						E	L	P	E	L	P
1-7-71	30	44.5	3.5	46.0	17.5	19	12	-	-	1	-
15-7-71	44	52.6	5.3	56.0	21.3	29	13	2	-	-	1
29-7-71	58	56.1	6.8	80.0	25.5	10	16	11	4	1	3
12-8-71	72	79.9	7.3	64.0	18.8	18	9	14	7	3	4
26-8-71	86	98.7	9.8	60.0	15.0	11	4	8	4	3	5
9-9-71	100	106.4	10.4	74.0	16.3	4	2	5	3	2	6
23-9-71	114	124.3	10.2	64.0	14.2	-	-	3	-	4	8
Total	-	-	-	-	-	91	56	43	18	14	27

Table 5 Diopsis infestation on rice at Kpong

November 1971 - February 1972

Date	Age of Rice (Days)	Mean Height (cm)	Mean No. of stalks per hill	% Infestation		Diopsis Species					
						D. thoracica			D. tenuipes		
				Hill	Stalk	E	L	P	E	L	P
16-11-71	16	25.7	2.1	8.0	3.9	4	-	-	-	-	-
30-11-71	30	41.5	4.3	14.0	5.2	6	2	-	-	-	-
14-12-71	44	51.9	6.3	30.0	7.2	10	4	-	5	1	-
28-12-71	58	67.7	7.4	42.0	11.0	4	6	1	9	2	-
11- 1-72	72	77.5	8.1	44.0	9.4	7	9	3	6	4	2
25- 1-72	86	104.4	7.6	40.0	9.1	2	4	6	3	2	4
8- 2-72	100	124.8	6.9	30.0	5.7	-	1	4	-	2	5
22- 2-72	114	130.9	6.5	34.0	5.9	-	2	2	-	-	2
Total	-	-	-	-	-	33	28	16	23	11	13

Table 6 Diopsis infestation on rice at Dawhenya

April - July 1971

Date	Age of Rice (Days)	Mean Height (cm)	Mean No. of stalks per hill	% Infestation		Diopsis Species					
				Hill	Stalk	D. thoracica			D. tenuipes		
						E*	L	P	E	L	P
1-4-71	15	26.3	6.5	6.0	2.3	-	-	-	-	-	-
15-4-71	29	42.3	10.9	36.0	5.2	3	-	-	-	-	-
29-4-71	43	61.0	16.0	46.0	12.5	10	3	-	7	2	-
13-5-71	57	66.2	16.2	60.0	17.1	14	7	-	18	5	-
27-5-71	71	76.4	15.8	58.0	21.3	6	12	2	23	9	4
10-6-71	85	80.1	16.1	58.0	10.7	4	10	6	13	12	4
24-6-71	99	102.5	15.7	56.0	8.3	5	3	8	8	4	6
8-7-71	113	109.3	15.9	54.0	7.0	-	1	3	12	2	3
Total	-	-	-	-	-	42	36	19	81	34	17

Table 7 Diopsis Infestation on rice at Dawhenya

July - October 1971

Date	Age of Rice (Days)	Mean Height (cm)	Mean No. of stalks per hill	% Infestation		Diopsis Species					
				Hill	Stalk	D. thoracica			D. tenuipes		
						E	L	P	E	L	P
8-7-71	16	25.0	6.3	10.0	2.5	4	1	-	-	-	-
22-7-71	30	40.3	11.3	40.0	6.0	17	11	-	-	-	-
5-8-71	44	60.1	15.7	94.0	21.9	57	51	1	7	3	-
19-8-71	58	68.2	15.3	100.0	48.4	15	55	19	16	8	1
2-9-71	72	75.3	14.0	100.0	35.4	22	6	40	33	4	8
16-9-71	86	81.5	15.3	98.0	30.4	12	3	38	-	8	12
30-9-71	100	104.5	15.4	80.0	10.9	4	2	6	-	9	7
14-10-71	114	110.2	14.1	72.0	7.3	-	2	2	-	2	5
Total	-	-	-	-	-	131	131	106	56	34	33

Table 8 Diopsis infestation on rice at Dawhenya
December 1971 - April 1972

Date	Age of Rice (Days)	Mean Height (cm)	Mean No. of stalks per hill	% Infestation		Diopsis Species					
				Hill	Stalk	D. thoracica			E. tenuipes		
						E	L	P	E	L	P
29-12-71	15	24.5	5.8	2.0	0.7	-	-	-	-	-	-
12-1-72	29	41.2	11.0	6.0	2.1	-	-	-	-	-	-
26-1-72	43	60.9	15.9	20.0	6.3	3	-	-	-	-	-
9-2-72	57	67.8	16.6	28.0	11.5	8	9	-	-	1	-
23-2-72	72	73.6	16.3	40.0	13.4	13	10	7	6	3	2
8-3-72	85	83.7	15.0	38.0	12.1	2	6	11	8	3	7
22-3-72	99	107.3	14.8	32.0	10.0	5	2	4	5	1	3
5-4-72	113	113.1	14.3	30.0	5.8	-	1	3	-	3	2
Total	-	-	-	-	-	31	28	25	19	11	14

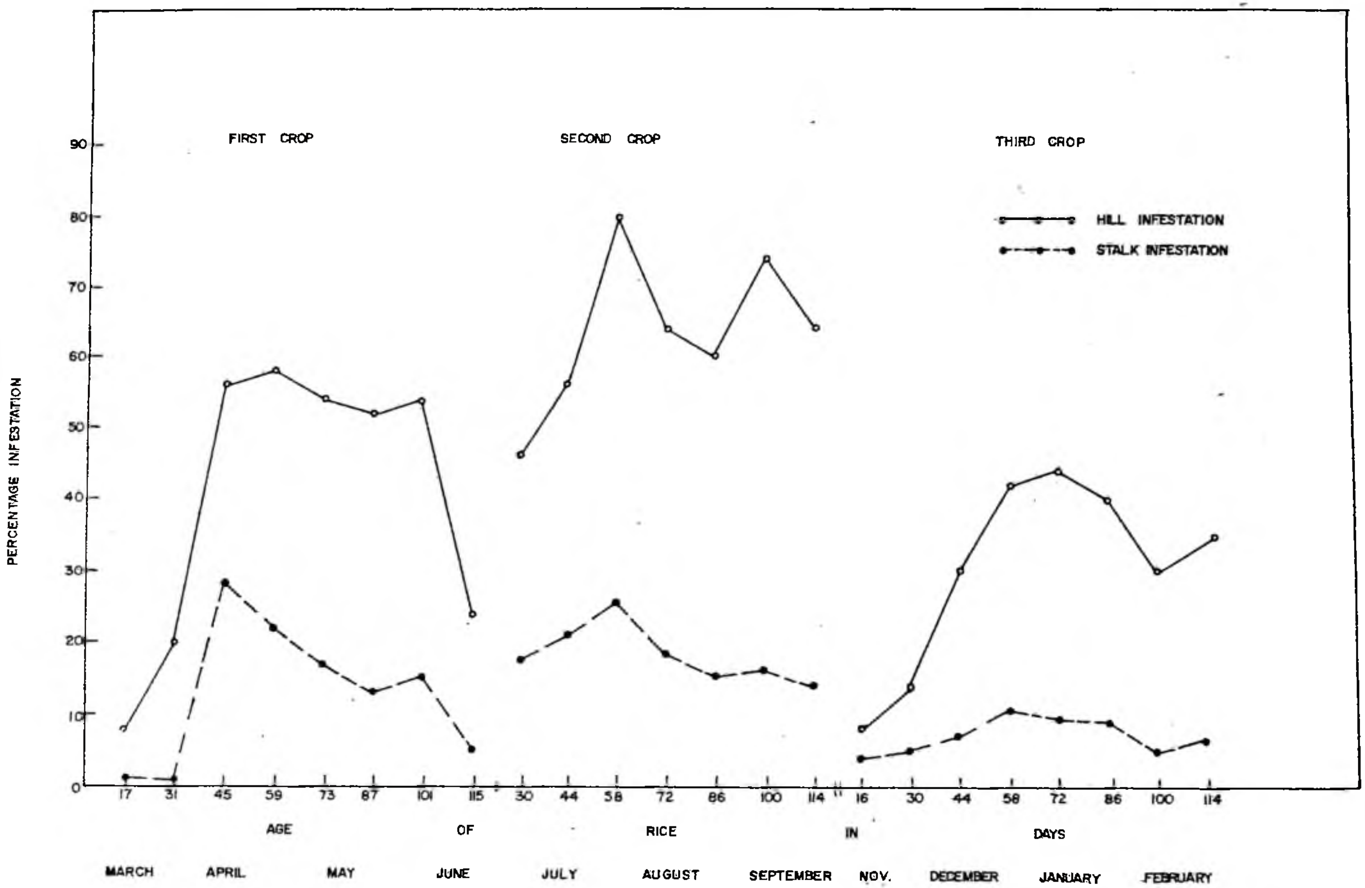


FIG. 7. DIOPSIS INFESTATION AT KPONG ; MARCH 1971 TO FEBRUARY 1972.

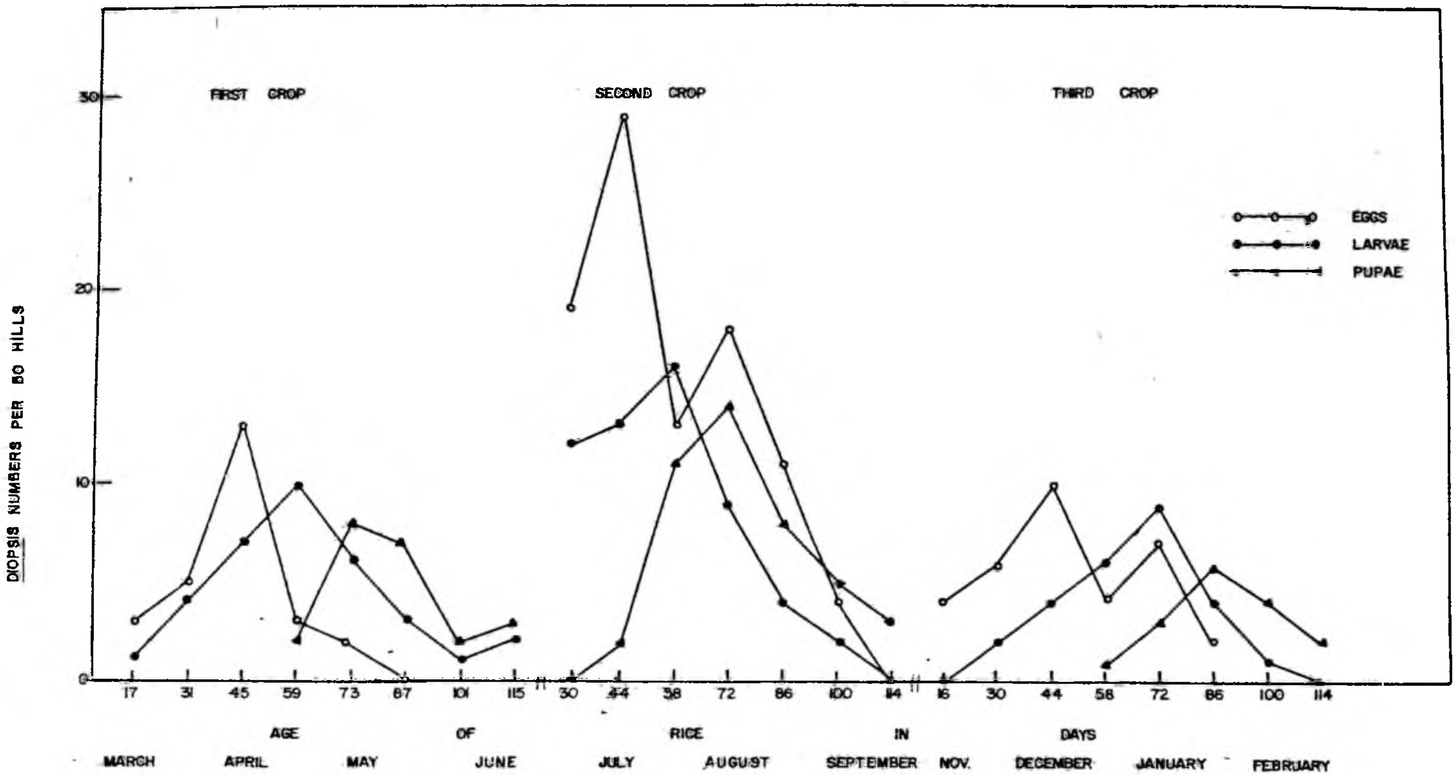


FIG. 8 ABUNDANCE OF DIOPSIS THORACICA AT KPONG ; MARCH 1971 TO FEBRUARY 1972.

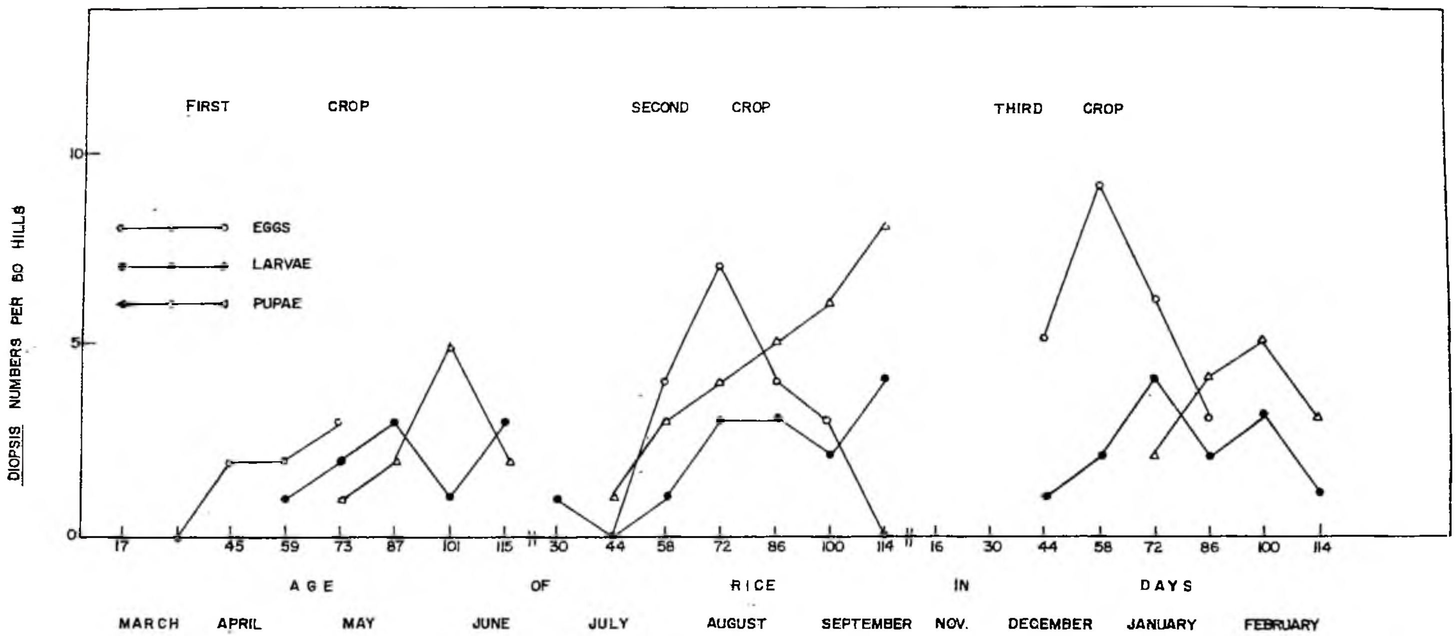


FIG 9. ABUNDANCE OF DIOPSIS TENUIPES AT KPONG, MARCH 1971 TO FEBRUARY 1972

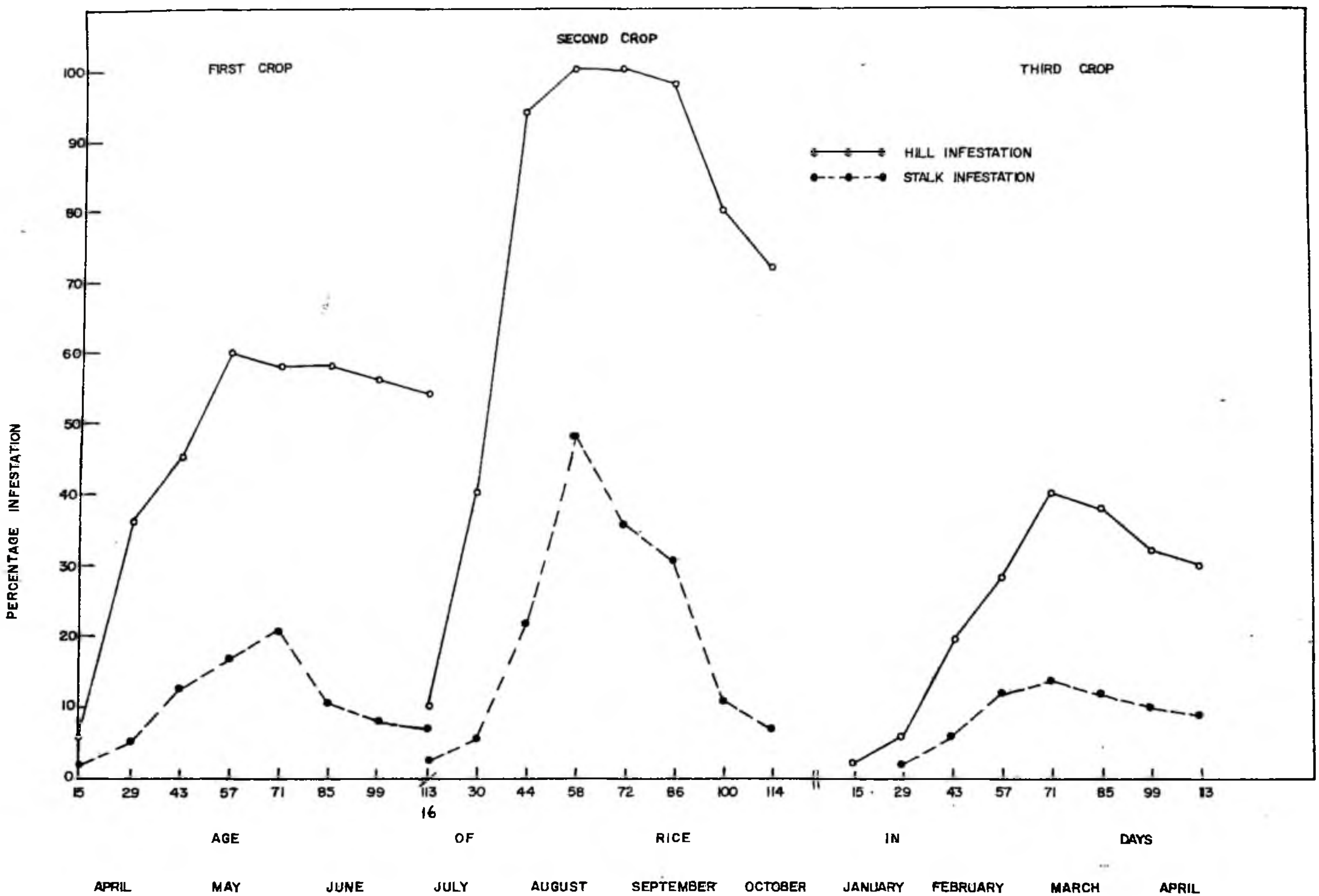


FIG. 10 DIOPSIS INFESTATION AT DAHWENYA ; APRIL 1971 TO APRIL 1972

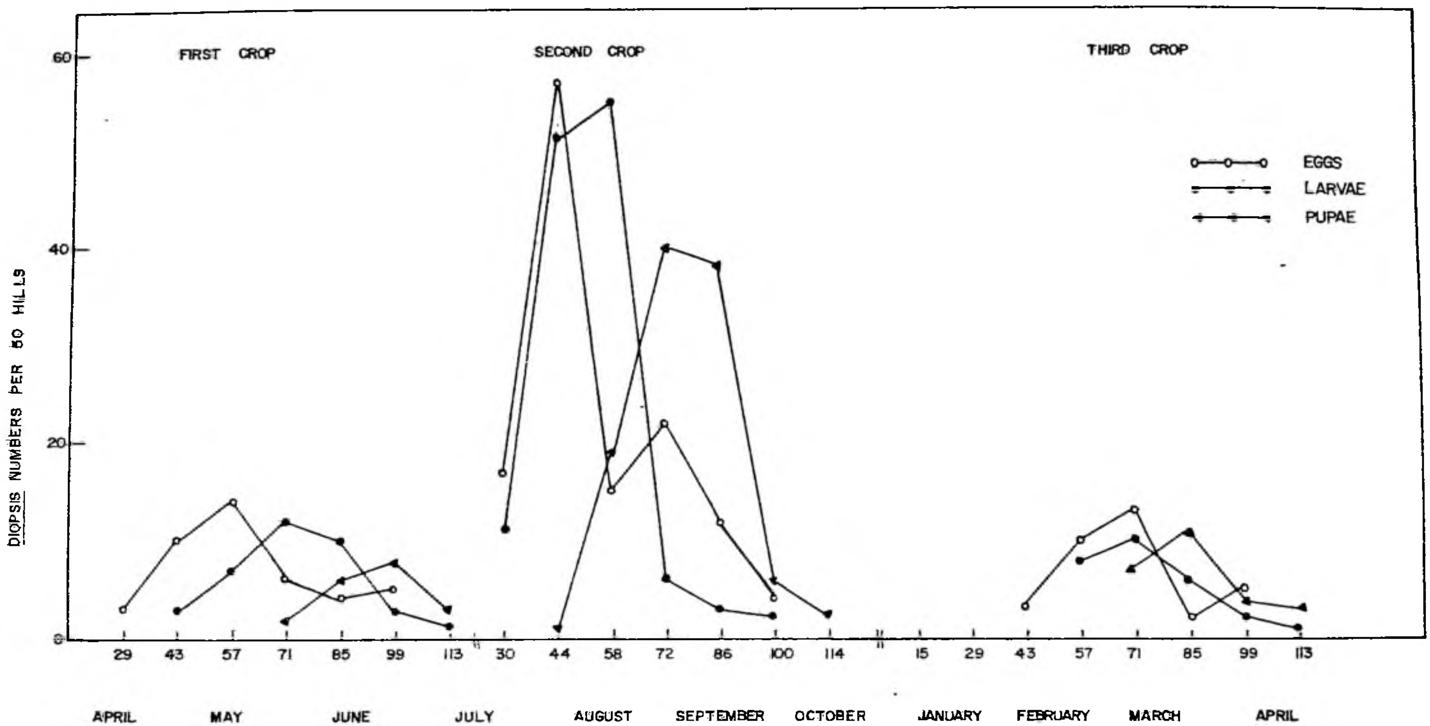


FIG. 11 ABUNDANCE OF <u>DIOPSIS</u> <u>THORACICA</u> AT DAHWENYA ; APRIL 1971 TO APRIL 1972

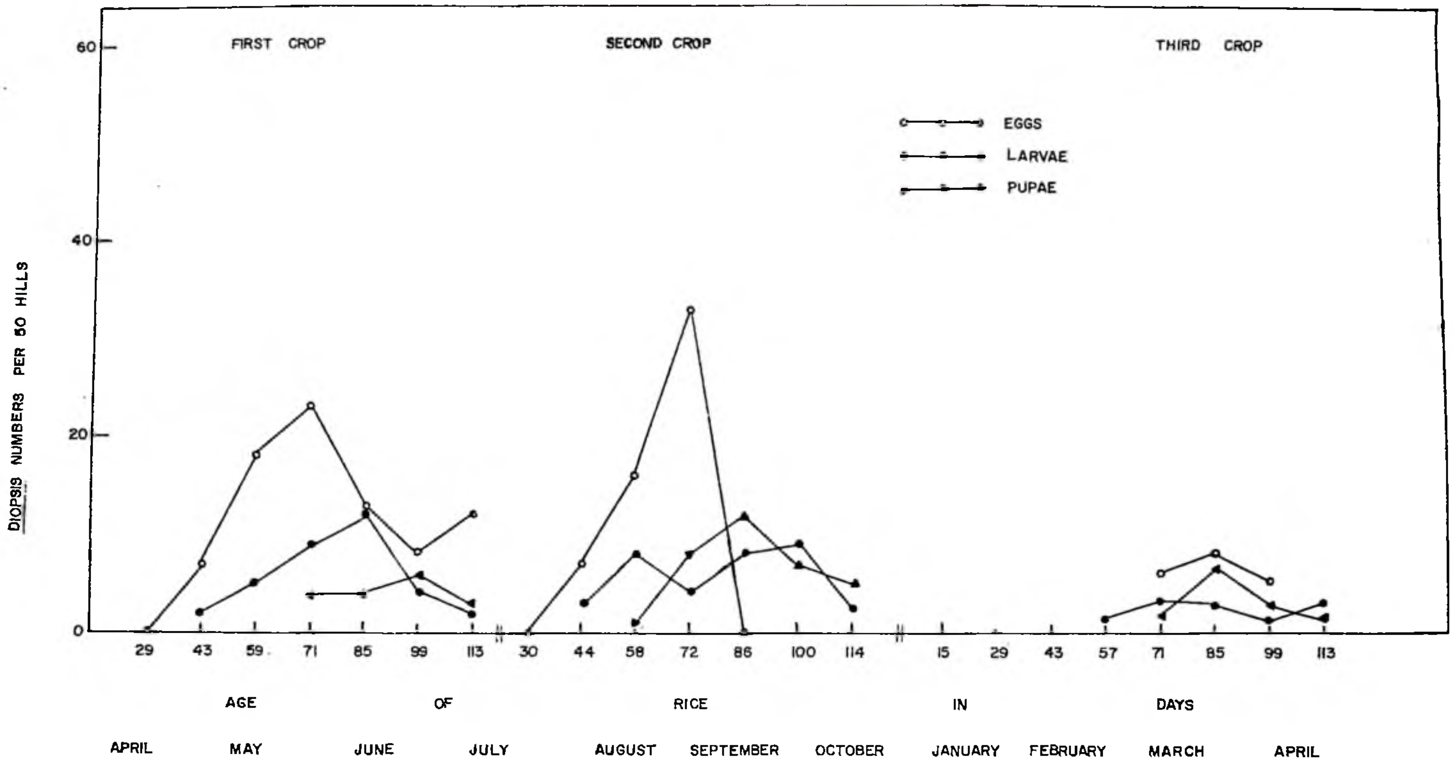


FIG. 12. ABUNDANCE OF DIOPSIS TENUIPES AT DAHWENYA, APRIL 1971 TO APRIL 1972.

Table 9 Adult Diopsis collected by net sweeping at Kpong March – June 1971

Date	Age of Rice (Days)	Diopsis Species			
		D. thoracica	D. tenuipes	D. ichneumonea	Diopsis spd
11-3-71	17	9	1	-	-
25-3-71	31	17	2	-	-
8-4-71	45	21	4	-	-
22-4-71	59	69	7	-	-
6-5-71	73	264	7	-	-
20-5-71	87	16	1	1	1
3-6-71	101	2	-	1	-
17-6-71	115	-	-	-	-
Total	-	398	22	2	1

Table 10 Adult Diopsis collected by net sweeping at Kpong July – September 1971

Date	Age of Rice (Days)	Diopsis Species			
		D. thoracica	D. tenuipes	D. ichneumonea	Diopsis spd
1-7-71	30	523	7	-	-
15-7-71	44	448	4	1	-
29-7-71	58	395	11	-	-
12-8-71	72	307	28	6	-
26-8-71	86	175	19	3	-
9-9-71	100	30	16	2	-
23-9-71	114	64	13	-	-
Total	-	1942	98	12	-

Table 11 Adult Diopsis collected by net sweeping at Kpong November 1971 - February 1972

Date	Age of Rice (Days)	Diopsis Species			
		D. thoracica	D. tenuipes	D. ichneumonea	Diopsis spd
16-11-71	16	2	1	6	-
30-11-71	30	9	5	10	-
14-12-71	44	36	21	18	1
28-12-71	58	17	12	11	-
11- 1-72	72	22	5	1	-
25- 1-72	86	53	17	7	1
8- 2-72	100	20	11	2	-
22- 2-72	114	7	4	-	-
Total	-	166	76	55	2

Table 12 Adult Diopsis collected by net sweeping at Dawhenya April - July 1971

Date	Age of Rice (Days)	Diopsis Species			
		D. thoracica	D. tenuipes	D. ichneumonea	Diopsis spd
1-4-71	15	-	7	-	-
15-4-71	29	12	10	-	-
29-4-71	43	47	9	-	-
13-5-71	57	23	6	-	1
27-5-71	71	11	4	-	-
10-6-71	85	2	6	-	-
24-6-71	99	3	-	-	-
8-7-71	113	2	-	-	-
Total	-	100	42	-	1

Table 13 Adult Diopsis collected by net sweeping at Dawhenya
July - October 1971

Date	Age of Rice (Days)	Diopsis Species			
		D. thoracica	D. tenuipes	D. ichneumonea	Diopsis spd
8-7-71	16	-	2	-	-
22-7-71	30	76	23	3	-
5-8-71	44	38	19	5	-
19-8-71	58	29	18	3	-
2-9-71	72	13	3	1	-
16-9-71	86	2	1	-	-
30-9-71	100	3	2	-	-
14-10-71	114	1	3	-	-
Total	-	162	71	12	-

Table 14 Adult Diopsis collected by net sweeping at Dawhenya
December 1971 - April 1972

Date	Age of Rice (Days)	Diopsis Species			
		D. thoracica	D. tenuipes	D. ichneumonea	Diopsis spd.
29-12-71	15	-	-	-	-
12-1-72	29	1	-	-	-
26-1-72	43	16	-	-	-
9-2-72	57	44	1	-	1
23-2-72	71	45	8	2	-
8-3-72	85	14	6	1	-
22-3-72	99	6	4	2	-
5-4-72	113	3	2	-	-
Total	-	129	21	5	1

Table 15 Relationship between % maximum hill and stalk infestation by Diopsis species, % heading and % whitehead

Place	Duration of Rice Crop	Max. Infestation (%)		Heading (%)	Whitehead (%)
		Hill	Stalk		
Kpong	March-June 1971	58.0	28.8	91.6	2.6
	June-Sept. 1971	80.0	25.5	89.3	3.7
	Nov.-Feb. 1971 1972	44.0	11.0	92.6	2.3
Dawhenya	April-July 1971	60.0	21.3	90.0	3.0
	July-Oct. 1971	100.0	48.4	89.7	3.6
	Dec.-April 1971 1972	40.0	13.4	91.5	2.6

Table 16 Sex ratios of Diopsis spp (Males : Females)

Plaee	Duration of Rice Crop	*D. thoracica*	*D. tenuipes*	*D. ichneumonea*
Kpong	March-June 1971	1 : 1.1	1 : 1.2	-
	June-Sept. 1971	1 : 1.3	1 : 1.1	1 : 1
	Nov.-Feb. 1971 1972	1 : 1.2	1 : 1.2	1 : 1.1
Dawhenya	April-July 1971	1 : 1.3	1 : 1.2	-
	July-Oct. 1971	1 : 1.2	1 : 1.2	1 : 1.4
	Dec.-April 1971 1972	1 : 1.2	1 : 1.3	1 : 1.5

and 11 show the abundance of D. thoracica at Kpong and Dawhenya respectively. Generally the peaks of the three developmental stages; eggs, larvae and pupae followed each other. The rainy season again recorded the greatest number of adults.

The abundance of D. tenuipes (Figs. 9 and 12) showed that the seasonal variations in numbers were not so marked as in D. thoracica. No immature stage of D. tenuipes was recorded at any of the first samplings, suggesting that this species started the attack on rice later than D. thoracica.

The sexes of adult diopsids occured in the field in about equal numbers (table 16). The sex ratios for D. thoracica and D. tenuipes ranged from 1 : 1.1 to 1 : 1.3 (males : females). For D. ichneumonea the range was 1 : 1 to 1 : 1.5. The inconsistency in the ratios for D. ichneumonea is probably due to its low populations in the field.

5.3 Seasonality of E. similis

Epilachna similis was absent from the Dawhenya farm. The incidence at Kpong is shown in tables 17 - 19. Short outbreaks occured at the beginning of each cropping season. The pest was virtually absent from plots beyond the age of 60 days. The outbreak was more serious at the beginning of the major rainy season in March 1971. At this period it was observed that a whole nursery for variety trials was completely destroyed by the larvae of E. similis at Kpong. The dry season from November to February recorded the lowest numbers of both immature stages

Table 17 E. similis collection at Kpong

March - June 1971

Date	Age of Rice (Days)	E. similis			
		Eggs	Larvae	Pupae	Adults
11-3-71	17	24	50	-	40
25-3-71	31	3	252	5	37
8-4-71	45	1	29	45	48
22-4-71	59	-	4	1	10
6-5-71	73	-	-	-	2
20-5-71	87	-	-	-	-
3-6-71	101	-	-	-	-
17-6-71	115	-	-	-	-
Total	-	28	335	51	137

Table 18 E. similis collection at Kpong

June - September 1971

Date	Age of Rice (Days)	E. similis			
		Eggs	Larvae	Pupae	Adults
17-6-71	15	20	19	2	25
1-7-71	30	4	23	4	13
15-7-71	44	-	12	18	2
29-7-71	58	-	7	3	9
12-8-71	72	-	-	-	-
26-8-71	86	-	-	-	-
9-9-71	100	-	-	-	-
23-9-71	114	-	-	-	-
Total	-	24	61	27	49

Table 19 E. similis collection at Kpong

November 1971 - February 1972

Date	Age of Rice (Days)	E. similis			
		Eggs	Larvae	Pupae	Adults
16-11-71	16	9	39	-	15
30-11-71	30	1	7	9	6
14-12-71	44	-	5	7	7
28-12-71	58	-	2	-	1
11-1-72	72	-	-	-	-
25-1-72	86	-	-	-	-
8-2-72	100	-	-	-	-
22-2-72	114	-	-	-	-
Total	-	10	53	16	29

and adults. The sex ratios ranged from 1 : 1.4 to 1 : 1.6 (males : females).

5.4 Discussion

5.4.1 Diopsis spp

Southwood (1966) has pointed out several limitations of sweeping with insect nets as the means of assessing insect populations. On the old rice plots visual observations indicated that most adult diopsids rest on the stalk and therefore would not be available to the stalk and therefore would not be available to the net. This could affect the estimate of the adult Diopsis spp.

The pattern of infestation and abundance of Diopsis at the two rice farms were essentially the same. All the three rice crop seasons had considerable Diopsis infestation irrespective of the time of the year. Thus these insects can thrive throughout the year so long as there is rice or other suitable host plants. However, infestation during the major rainy season was higher than during the other two seasons.

D. thoracica occured in far larger numbers than D. tenuipes. This would suggest that the former species was responsible for most of the damage done to the crop. Secondly D. tenuipes had the tendency to attack already infested plants and therefore would not cause as much damage to the rice crop as would D. thoracica.

It was noted that adult diopsids occured in higher numbers at Kpong than at Dawhenya. This could be due to several factors such as cultural methods and the differences in the environment. Although the effects of the first factor cannot be overruled it may be assumed from the ecology of these insects that the environmental conditions have an important influence. Diopsids prefer humid climates where the dry season is not too severe (Descamps, 1957a;b). They pass the dry season in moist places, near more or less permanent ponds with evergreen vegetation where there is some form of shade. Situated at the extreme north of the Accra Plains, and close to the Volta River Kpong experiences a more humid climate than Dawhenya (Appendices 1, 2) for the greater par of the year and thus provides a more suitable for these insects. The low infestations recorded in the dry season from November to February strongly supports the observations of Descamps (1957a; b), Van Bruggen (1961) and Breniere (1969) that climate factors have a pronounced influence on the abundance of diopsids.

The incidence of "whitehead" was very low. This could be due to the fact that infestation by Diopsis usually starts during the early growth stages of the rice plant and most of the insects leave the crop before panicle initiation, when infestation is likely to cause the "whitehead" condition.

5.4.2 E. similis

The sampling method adopted for E. similis appears to have one defect. This insect has a short life cycle and the two week intervals between samples might be too long. This could be the cause of the sharp rise and fall in the population of the immature stages particularly on the first rice crop (table 17). The disadvantages of estimating insect populations with sweeping nets have already been pointed out in section 5.4.1. The hibernating habit of E. similis make the adults unavailable to the nets when the rice plants are old because most of them rest between the stalks. Such a limitation could partly account for the failure to record adults on the old rice plots.

Like the Diopsis spp, E. similis thrives throughout the year. The greatest population of E. similis was recorded on the first crop grown from March to June.

The occurrence of the immature stages of E. similis only at the beginning of a new crop supports the observation made in section 4 that the adults of this species undergo a form of hibernation. The young adults emerging on old rice stalks would not find adequate nutrition and they therefore hibernate either on the old rice or probably on nearby weeds, later migrating to new rice crops.

6. PARASITES AND ALTERNATE HOSTS

6.1. Parasites

The immature stages collected from the field were individually reared in the laboratory and the parasites which emerged from them were recorded.

6.1.1. *Diopsis* spp.

(a) *Trichogramma* (*Xanthoatomus*) sp. (Hymenoptera; Trichogrammatidae). This species parasitized the eggs of *D. thoracica* and *D. tenuipes* both at Kpong and Dawhenya. The degree of parasitism was greater at Kpong where up to 70% (76 out of 109) of the eggs of both *Diopsis* species collected during the life of the second rice crop were attacked by *Trichogramma*.

(b) *Tetrastichus* (*Aprostiоetus*) sp. (Hymenoptera; Eulophidae).

This species was recorded as a pupal parasite of *D. thoracica*. The maximum parasitism recorded at Kpong and Dawhenya were 80% (34 out of 43) and 65% (11 out of 17) respectively. Again this parasite was most prevalent on the diopsids which attacked the second rice crop.

(c) *Trichopria* sp. (Hymenoptera; Diapriidae).

This species parasitized the pupae of *D. tenuipes* at Dawhenya where it was recorded only on two occassions. On each occassion only one pupa was parasitized.

6.1.2. Epilachna similis

(a) Ooencyrtus sp. (Hymenoptera; Encyrtidae).

This species was recorded at Kpong and Legon on the egg of E. similis. Field parasitism of E. similis by this insect occured throughout the year, but never exceeded 25% (6 out of 24) of the total egg batches collected.

(b) Pediobius sp. (Hymenoptera; Eulophidae).

This species emerged from the pupae reared from fourth instar larvae of E. similis collected at Kpong. The maximum recorded parasitization of E. similis larvae by Pediobius was 50% (5 out of 10). This occured during the third rice crop.

6.1.3. Discussion

Some species of the three genera parasitizing Diopsis spp. have already been found in the Cameroons and Sierra Leone, but information on the abundance and regional distribution of the parasites of Diopsis in West Africa is lacking. Both Risbec (1956) and Descamps (1957 a;b) have listed a number of parasites of Diopsis spp. in the Cameroons. These lists include species of the following genera-:

Tetrastichus	(Hymenoptera; Eulophidae)-Pupal parasite
Pleurotropis	(" " " "
Eurytoma	(" Eurytomidae) " "
Eupelmella	(" Eupelmidae) " "
Opius	(" Braconidae) " "

Bracon	(Hymenoptera; Braconidae) Larval parasite
Trichopria	(" Diapriidae) Pupal "
Dirhinus	(" Chalcididae) " "
Diourbelia	(" ") " "
Trichogramma	(" Trichogrammatidae) Egg parasite
Steleocefus	(Diptera; Chloropidae) Larval parasite

In Sierra Leone Jordan (1966) found Tetrastichus as a pupal parasite while Morgan (1970) recorded Apanteles, a braconid, as a larval parasite of Diopsis. The reports of these authors indicate that of the three parasites recorded in this work Trichogramma and Tetrastichus attach several species of Diopsis while Trichnopria has been found attacking only D. tenuipes and D. collaris. The parasitization of D. thoracica needs special mention since this is the most destructive diopsid on rice. Descamps (1957a) gave three major parasites which, to a large extent, limited the population of D. thoracica in Northern Cameroon. Trichopria aethiopicus Risbec parasitized 50-70% of the eggs, Steleocerus lepidopus Becker attacked 30-80% of the larvae and Tetrastichus diopsisi Risbec killed about 70% of the pupae.

The list of the parasites of Diopsis spp is most probably incomplete. Only intensive studies in different areas of West Africa will provide the basis for a more complete list.

None of the two genera found as parasites of E. similis in this work has been recorded in any of the available literature. Apparently the only available information on the parasites of E. similis in West Africa is that of Descamps (1956). He listed the following three parasites of E. similis in Northern Cameroon.

(i) Tetrastichus cydoniae Risbec (Hymenoptera; Eulophidae) - Pupal parasite

(ii) Pleurotropis mediopunctata Wat. (Hymenoptera; Eulophidae) - Pupal parasite

(iii) Paralitomastix polyphaga Risbec (Hymenoptera; Encyrtidae) - Egg parasite.

It should be noted that some species of the first two genera are also parasitie on Diopsis spp.

Since all the immature stages of E. similis are found outside the plant host they are likely to be attacked by several parasites. The up to date list of parasites of E. similis is certainly incomplete.

6.2. Alternate Hosts

During field visits a careful watch was kept for any Diopsis spp or Epilachna similis on plants other than rice. Such plants were recorded as host plants only when they were being fed on by the larvae of Diopsis spp or the adults and the larvae of E. similis.

In the course of the study my attention was drawn to the presence of some of these insects at the Legon University farm where no rice is grown. I made occassional visits to this farm to observe and collect possible host plants of these insects.

The altenate host plants found at the localities visited are recorded below. No alternate host of *D. thoracica* was found.

6.2.1. *Diopsis* spp.

(i) *Diopsis tenuipes*

(a) *Sorghum guineense Stapf* (Gramineae) - Legon

(b) *Brachiaria lata* Schumach, Hubbard (Gramineae) - Kpong, Dawhenya and Legon

(c) *Echninocloa colonum* L., Link (Gramineae) - Kpong and Dawhenya

(ii) *Diopsis ichneumonea*

(a) *Brachiaria lata* Schumach, Hubbard (Gramminеae) - Kpong, Dawhenya and Legon.

(b) *Echinocloa colonum* L., Link (Gramineae) - Kpong and Dawhenya.

6.2.2. *Epilachna similis*

(a) *Zea mays* L.,(Gramineae) - Kpong and Legon

(b) Sorghum guineense stapf (Gramineae) - Legon

(c) *Cyperus rotundus* L. (Cyperaceae) - Kpong

(d) Commelina nudiflora L. (Commelinaceae) - Kpong

(e) Echinocloa colonum L. Link (Gramineae) - Kpong

6.2.3. Discussion

Apart from D. thoracica all the diopsids known in West Africa have been found on various graminaceous plants. Descamps (1957a;b) listed the following genera of Gramineae as altenate hosts of Diopsis spp in the Cameroons-:
Echinocloa; Panicum, Pasparum, Urochloa, Pennisetum, Chloris, Setaria, Digetaria, Imperata, Dactyloctenum and Sorghum. Thus with the exception of Brachiaria all the plants recorded in this work as altenate hosts have been found elsewhere as host plants of the Diopsis spp. Unlike the other diopsids, D. thoracica is less polyphagous and has not been recorded, up to date, on any other plant apart from those belonging to the genus Oryza. The fact that some of these diopsids are found at places where no rice is grown suggests that some species of the Diopsis may be associated with wild grasses.

Epilachna similis is very polyphagous. Although it can be deduced from the literature that this species attacks a wide range of graminaceous plants, it is not restricted to the Gramineae because of its recorded occurrence on Cyperaceae and commelinaceae. In Nigeria Peacock (1914) recorded E. similis on cotton which belongs to the family Malvaceae.

Most of these altenate hosts of *Diopsis* spp and *E. similis* are common weeds of rice farms and could harbour the pests when the plots are left to fallow, thereby acting as reservoirs for future infestation of subsequent rice crops.

7. EXPERIMENTS WITH *DIOPSIS THORACICA* AND *EPILACHNA SIMILIS*

7.1 Damage Caused by *D. thoracica* and its Effect on the Yield of Rice

It has been established in section 5 that *D. thoracica* is the major stem borer of rice in the Accra Plains, damaging up to about 48% of the stalks in the field. As stated by Schroder (1971) and confirmed in this investigation infestation starts when the plant is a few weeks old. At this stage the rice plant has the ability to tiller to compensate for the lost stalks. In the opinion of Akinsola (1970) this process of compensatory tillering could be enough to overcome the effect of the infestation and thus there might not be any appreciable loss in yield. To test the validity of this theory an investigation was conducted under controlled conditions. The main aim was to assess the effect of *D. thoracica* on tillering and yield at various stages of growth of the rice plant and at different intensities of stalk infestation.

7.1.1 Materials and Methods

The methods employed for this experiment were modified from Kok and Varghese (1966a). The experiment was carried out from 10th August 1971 to 2nd January 1972 in an insect-proof greenhouse with a glass roof and walls made of 0.2mm wire mesh. The temperature and relative humidity ranges within the green house were 23.5-30.8°C (mean = 25.6°C) and 65-85% (mean = 79%) respectively. Seeds of the rice variety C4 - 63 were nursed in the green house on 21st July and transplanted on 10th August 1971, when they were 20 days old, into wooden boxes measuring 40cm x 40cm at the bottom and 40cm in height. Each box was filled to a depth of 30cm with soil of the Black clay series. Initially six seedlings were planted per box but this was thinned down to four after 21 days. The level of water above the soil was maintained between 3 - 5cm throughout the experiment.

Freshly hatched larvae of D. thoracica were used for the infestation. The rice stalks were artificially infested by introducing the larvae with the aid of a camel hair brush. The larvae were watched till they bored into the stalk.

The layout was a factorial experiment embodying rice plants of three age groups and five intensities of larval infestation. There were a total of fifteen treatments in a randomized block design with four replicates. The plant age groups were:-

(1) 21 days after transplanting

(2) 60 days after transplanting

(3) 90 days after transplanting

The intensities of larval infestation were as follows:-

(1) 0% intensity - Control

(2) 25% " - 1 larva to 4 tillers

(3) 50% intensity - 1 larva to 2 tillers

(4) 75% " - 3 larvae to 4 tillers

(5) 100% " - 1 larva to 1 tiller.

The records taken were:-

(i) The number of tillers at the time of infestation

(ii) The number of tillers after 30 days of infestation

(iii) The number of infested tillers after 30 days of infestation

(iv) The number of tillers at maturity

(v) The number of panicles at maturity

(vi) The number of "whiteheads" at maturity

(vii) The clean grain yield.

From (ii) and (iii) the percentage stalk infestation after 30 days was calculated. The percentage "whitehead" was calculated from (v) and (vi).

To prevent re-infestation the plants were checked 35 days after infestation and any pupae formed were removed. The grains were harvested on 2nd January when they were fully ripe.

Analysis of variance based on maximum tillers at maturity and clean grain weight were carried out. Differences between the effects of the age and intensity of infestation were tested with the Duncan's Multiple Range Test.

7.1.2 Observations and Results

The recordings are summarized in table 20. Table 21 and 22 show the effects of the treatments on the tillering and grain yield respectively. The analysis of variance on the tillering and yield are summarized in appendices 4 and 5.

Plants infested at 21 days old showed the deadheart symptom within one or two days while at 60 days or 90 days the symptoms showed after four days. At 21 days old the 100% infestation killed most of the stalks before they could produce tillers. In changing stalks most larvae selected new tillers. Plants infested at 21 days never showed the "whitehead" symptoms which was most prevalent on plants infested at 60 days.

The treatments had highly significant effects on the tillering and yield and there were high interactions between age and intensity of infestation. Tillering was increased by infestation intensities of 25% and 50% but decreased by the 75% and 100% levels. The increase or decrease was more pronounced when infestation was on 21day-old plants. The yields showed that the controls were significantly better than all the other treatments. The loss in yield was proportional to the increase in intensity of infestation.

Table 20 Artificial Infestation of Rice Stalks with Larvae of *D. thoracica*

Treatment	AT INFESTATION		30 DAYS AFTER INFESTATION			AT MATURITY					
	No. of Tillers	No. of Larvae	No. of Tillers	Infested Tillers	% Infestation	No. of Tillers	No. of Panicles	No. of Whitehead	% Whitehead	Grain Yield (gm)	% Loss in Yield +++
+ x ++											
21 x 0	4	0	10	0	0	21	18	0	0	90.25	0
21 x 25	4	1	14	4	28.6	24	19	0	0	81.50	9.15
21 x 50	4	2	11	6	54.5	23	20	0	0	72.00	20.23
21 x 75	4	3	10	6	60.0	15	10	0	0	51.75	42.66
21 x 100	4	4	6	6	100.0	14	11	0	0	39.25	56.51
60 x 0	17	0	20	0	0	22	21	0	0	81.00	0
60 x 25	16	4	18	3	16.1	22	20	2	10.0	76.00	6.17
60 x 50	17	9	21	5	23.8	21	16	2	12.5	70.25	13.27
60 x 75	16	12	19	6	31.6	22	14	3	21.4	59.50	26.54
60 x 100	17	17	20	6	30.0	23	17	9	52.9	62.25	23.15
90 x 0	22	0	22	0	0	23	21	0	0	89.50	0
90 x 25	22	6	23	4	17.0	22	20	2	10.0	76.75	14.24
90 x 50	21	11	20	6	30.0	21	20	1	5.0	75.00	16.21
90 x 75	20	15	22	9	40.9	22	19	2	10.5	70.00	21.79
90 x 100	21	21	24	12	50.0	22	17	1	5.9	70.25	21.51

Figures represent the means of four replications.

\+ - Age of Rice in Days.
++ - Percentage stalk Infestation.
+++ - AS % of yield in Control.

Table 21 Effect of Intensities and Age of Infestation with Larvae of *D. thoracicia* on Tillering of Rice

% Infestation	Age of Rice (Days)			Average Effect of Infestation
	21	60	90	
	Age x Infestation Means			
0	21	22	23	22
25	24	22	22	23
50	23	21	21	22
75	15	22	22	20
100	14	23	22	20
Average Effect of Age	19	22	22	

Duncan's Test on the Effect of different rates of larval infestation on the tillering of rice plants infested at 21 days old:-

Infestation level	100%	75%	Control	50%	25%
Mean No. of Tillers	14	15	21	23	24

(14 and 15 underscored by one line; 21 and 23 underscored by one line; 23 and 24 underscored by one line.)

Any two means not underscored by the same line are significantly different at the 1% level. Any two means underscored by the same line are not significantly different at that level.

Table 22 Effect of Intensities and Age of Infestation with Larvae of D. thoracicia on Yield of Rice (gm)

% Infestation	Age of Rice (Days)			Average Effect of Infestation
	21	60	90	
	Age x Infestation Means			
0	40.3	81.0	89.5	86.9
25	81.5	76.3	76.8	78.1
50	72.0	70.3	75.0	72.4
75	51.8	59.5	70.0	60.4
100	39.3	62.3	70.3	57.3
Average Effect of Age	67.0	69.8	76.3	

(i) Duncan's Test on the average effect of the level of larval infestation on grain yield of rice:-

Infestation level	100%	75%	50%	25%	Control
Mean yield (gm)	57.3	60.4	72.4	78.1	86.9

(ii) Duncan's Test on the average effect of age of larval infestation on the grain yield of rice:-

Age of Infestation	21days	60days	90days
Mean yield (gm)	67.0	69.8	76.3

All the differences between means in both (i) and (ii) were significant at the 1% level.

7.1.3 Discussion

The results of the experiment clearly illustrate that significant yield losses were caused by the infestation, but the extent of losses was dependent both on the age when infestation occured and the intensity of infestation. 21 days-old plants infested at 25% intensity were less seriously affected because they had a chance of recovering by producing new tillers. Actually plants at this age and intensity of infestation produced more tillers as compared to the control. However, the yield was lower because many of the tillers did not carry grains or bore smaller panicles.

A comparison between the yields at 60 days and 90 days indicated that the former suffered heavier losses at all the different rates of infestation. At 60 days old the rice plant no longer has the ability to tiller, but is comparatively fresh to support the larvae. At 90 days, survival of the larvae on the plants is expected to be lower.

The yields estimated under these controlled conditions are not the same as those expected in the field because the plants could be limited in their growth. However, these results can be regarded as indicative of the minimum effects on yields due to Diopsis thoracica infestation.

7.2 Food Preference and Survival Tests with Larvae of E. similis

From the literature it is known that E. similis feeds on various cereal crops. In section 6 two important cereals of Ghana, maize and sorghum were recorded as altenate hosts to this insect. The aim of the following two experiments was to find out which of the major cereals is most preferred and to ascertain if all of them could support *E. similis* to maturity.

7.2.1 Food Preference Test

(i) Materials and Methods

Leaves of two weeks old seedlings of the four cereals, rice, maize, sorghum and millet were used as test materials. Strips of leaves measuring 0.5cm x 9cm were hung in 3cm x 10cm glass vials by fixing the strips to the cork stopper with pins. Four strips were hung in each vial and they were of the following combinations:-

A. Rice alone - 4 strips of the leaves

B. Maize alone - " " " " "

C. Sorghum alone - " " " " "

D. Millet " - " " " " "

E. Rice + Millet - 2 strips each of the leaves

F. Rice + Maize - " " " " " "

G. Rice + Sorghum - " " " " " "

H. Maize + Millet - " " " " " "

I. Maize + Sorghum - " " " " " "

J. Millet + Sorghum - " " " " " "

K. Rice + Millet + Sorghum + Maize - 1 strip each of the leaves.

The strips were hung in such a way that they were about 1cm from the bottom of the vial and did not touch each other nor the sides of the vial. Four freshly emerged first instar larvae of E. similis starved for twenty-four hours were placed at the bottom of the vial, which was kept upright throughout the experiment.

The number of larvae feeding on each strip of leaf was recorded after one hour.

(ii) Observations and Results

Larvae were observed to move along the sides of the vial. At the top they walked on the surface of the cork till they came into contact with a suitable leaf. Once feeding had started the larvae scarcely moved further. In A, B, C, and D which contained only one species of test plant each the larvae were observed to feed on the food offered. Observations in combinations E - K are tabulated below.(Table 23).

A plus sign indicates that the leaf was fed on and a minus sign indicates that there was no feeding. Figures following the plus signs show the total number of larvae found feeding on the leaf after one hour.

There was a marked preference for maize and sorghum as compared to rice. Millet was fed on only in A where the larvae had no choice.

Table 23 Food Preference in the Larvae of *E. similis*

Combination	Test	Plants		
E	Rice +4	Millet -		
F	Rice +1	Maize +3		
G	Rice +2	Sorghum +2		
H	Maize +4	Millet -		
I	Maize +3	Sorghum +1		
J	Millet +1	Sorghum +3		
K	Rice -	Millet -	Sorghum +1	Maize +3

7.2.2 Survival Test

(i) Materials and Methods

Two weeks old potted seedlings of rice, sorghum, millet and maize were used. On each potted plant was put one freshly emerged first instar larva of *E. similis* and the plant covered with a lantern glass globe of size 10 x 15cm. There were ten sets of this experiment for each species of test plant. The number of larvae that remained alive on each of the test plants was recorded at 2 days intervals. The duration of the instars was also noted.

(ii) Results

All the larvae on rice, sorghum and maize survived. Survival on millet was, however, poor. Only two out of the ten larvae pupated. The duration of the instars is summarized in Table 24.

Table 24 Mean Duration of Larval Instars of E. similis on Four Major Cereals of Ghana

Instar	Mean Duration of Instar (Days)			
	Rice	Sorghum	Millet	Maize
1	3.3	3.2	4.2	3.1
2	2.8	2.3	3.6	2.1
3	3.3	3.1	3.4	2.2
4	4.2	3.2	5.0	3.2
Total	13.6	11.8	16.2	10.6

Larval development was more rapid on maize but delayed on millet. All larvae that pupated emerged as adults and there was no difference in the duration of the pupae.

7.2.3 Discussion

In the first experiment it was noted that the larvae of E. similis can feed on any of the four crops, but exhibit some preference which was in the order:-

Maize, Sorghum, Rice, Millet. The results of the second experiment support the findings in the first experiment. There was high survival on the crops which are preferred. The low preference and the low survival observed on millet may be due to the inability of the larvae to move freely on the surface of the leaves. The leaves of this crop. are very hairy and could impede larval movements.

8. CONCLUSION

8.1 Diopsis spp.

It is evident from the foregoing account that the diopsids can be very destructive to rice in the field. Diopsis thoracica in particular posesa threat to the cultivation of this crop in the area investigated. A single larva of this pest per hill of rice could reduce grain yield by as much as 9.15%. In the rainy season when almost every hill is attacked, and there are often 2 - 4 larvae per hill, the total grain loss will be very high. The compensatory tillering induced by these borers in the rice does not appear to have any appreciable advantage when the infestation is heavy, because under such a situation the plant cannot cope with the attack. Furthermore the overlapping generations in the field can lead to reinfestation and these new tillers will be destroyed.

Van Halteren (1970) concluded that there was no need to adopt any control measures against D. thoracica. Over 48% stalk infestation was recorded at Dawhenya in the rainy season. Such a level of infestation can lead to heavy losses in yield and attack by Diopsis spp cannot therefore be ignored completely. Chemical control of the diopsids is likely to prove difficult since the larvae occur, for most of their life, in the stalks. Since eggs are more liable to come into direct contact with chemicals an insecticide with ovicidal properties will be more efficient. Applications might be timed to protect the crop at the more vulnerable stages of growth; for instance from a week or two after transplanting to two months. It is likely that systemic insecticides will be more effective. The use of resistant varieties of rice which is one of the major approaches to the control of lepidopterous stem borers can as well be adopted against diopsid borers. A physical feature of rice such as tight sheaths will make it very difficult for larvae to enter or leave the stalks. Both Schroder (1971) and Simmonds (1970) have stressed the use of biological control methods against these larval borers. This is quite feasible and probably will not involve much expenditure since a number of natural enemies were recorded in the present investigation. Risbec (1956) has also given a comprehensive list of parasites of the diopsid borers in the Camerouns. An integrated control approach embracing some of these outlined methods seems to be the most appropriate.

8.2 *Epilachna similis*

The damage caused by *E. similis* at Kpong is very low and may not be economically significant. It is only at the beginning of the rainy seasons that some precautions may have to be taken. Rice nurseries in particular will require some protection against this pest. The larvae, which are the most destructive to the crop, are exposed on the leaves and can therefore be easily killed by spraying an insecticides. The pest occurs in short outbreaks only at the early life of the crop.

Thus the plants can be sprayed once or twice at the beginning of the cropping seasons.

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10. APPENDICES

Appendix 1 Meteorological Data - Kpong

	Marc	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Aver-age
Mean Max. Temp. °C	34	33	34	30	29	29	31	32	33	32	34	35	32
Mean Min. Temp. °C	23	23	22	22	21	21	20	19	20	19	21	23	21
Monthly rainfall in cm	14.58	5.50	6.60	15.98	14.30	11.28	12.88	20.55	1.58	4.23	0.14	10.13	9.81
No. of rainy days	10	9	6	18	15	11	16	15	5	4	1	8	10
Mean RH at 09.00hrs (%)	84	83	82	87	87	85	81	79	78	81	82	83	83
Mean RH at 15.00hrs (%)	69	71	74	75	67	70	71	69	69	67	68	69	70

Appendix 2 Meteorological Data - Dawhenya

	1971 Mar.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1972 Jan.	Feb.	Mar.	Average
Mean Max. Temp. °C	33	33	32	28	28	30	31	34	35	36	35	33	32
Mean Min. Temp. °C	24	23	23	22	21	22	22	23	25	24	23	24	23
Monthly rainfall in cm	6.00	6.35	15.25	12.00	5.50	6.00	9.75	1.05	2.25	1.50	3.73	6.04	6.29
No. of rainy days	6	7	13	7	5	7	8	4	2	2	2	5	6
Mean RH at 09.00 hrs (%)	78	78	79	80	81	78	76	74	77	80	80	79	78
Mean RH at 15.00 hrs (%)	67	64	68	70	73	70	69	66	64	64	65	65	67

Appendix 3 Summary of the t-test on adult *D. thoracica*

	Length of Body (mm)		Inter-Orbital Distance (mm)	
	Males	Females	Males	Females
No. Measured	50	50	50	50
Mean	8.09	8.03	13.18	11.69
Difference of Means	0.06		1.49	
Standard Deviation (SD)	0.19	0.02	0.61	0.40
Combined SD	0.04		0.10	
Degrees of Freedom	49	49	49	49
Combined DF	98		98	
Observed t	1.50 NS		14.90**	
Required t 5%	1.98		1.98	
1%	2.63		2.63	

Appendix 4 Analysis of Variance table for number of rice tillers at Maturity

Source of Variation	df	ss	ms	Observed F	Required F 5%	Required F 1%
Total for Treatments	59	767.65				
Blocks	3	112.98	37.66			
Treatments	(14)	464.40	33.17	7.32**	1.94	2.54
Age of Rice (A)	2	114.10	57.05	12.59**	3.22	5.15
Infestation (I)	4	68.57	17.14	3.78*	2.59	3.80
Interaction A x I	8	28.73	35.21	7.77**	2.17	2.96
Error	42	190.27	4.53			

Appendix 5 Analysis of Variance table for clean grain yield (gm)

Source of Variation	df	ss	ms	Observed F	Required F 5%	Required F 1%
Total for Treatments	59	17344.58				
Blocks	3	2229.91	743.30	[illegible]	[illegible]	[illegible]
Treatments	(14)	8948.28	639.16	161.40**	1.94	2.54
Age of Rice (A)	2	674.63	337.32	85.18**	3.22	5.15
Infestation (I)	4	4300.66	1075.17	271.51**	2.59	3.80
Interactions A x I	8	3972.99	496.62	125.41**	2.17	2.96
Error	42	166.39	3.96			

Appendix 6 Meteorological Data - Greenhouse Experiment August - December 1971

Month	Monthly Mean Temp. °C		Monthly Mean RH (%)	
	Min.	Max	09.00hrs	15.00hrs
August 1971	22.0	26.5	85	74
September 1971	22.3	27.4	83	73
October 1971	23.1	28.6	80	72
November 1971	23.3	30.4	79	70
December 1971	23.5	30.9	82	67